

# Modelación Aplicada del Océano

## Curso Básico - CROCO

Andrés Sepúlveda

Departamento de Geofísica  
Universidad de Concepción

12 Enero 2022

# Anuncios

- Hoy: **Biogeoquímica**

## Aspectos Generales

- Existen varias formas de representar los procesos biológicos en CROCO
- Todas ellas son simplificaciones que se basan en los modelos de caja (*box model*), en las cuales son contenedores de una serie de variables (e.g. clorofila), y donde hay flechas que representan conversiones entre una y otra variable
- Estas conversiones son tasas de cambio que parametrizan procesos
- Estas tasas de cambio dependen de parámetros que pueden o **no** haber sido medidos en la zona de interés. En caso de no tener mediciones, usamos valores de la literatura, para ese u otro lugar
- Además tenemos el transporte desde otros lados, el efecto de la capa de mezcla, la temperatura...
- Si la física está mal, la Biogeoquímica no saldrá bien

- Hay 4 modelos bioquímicos en CROCO

```
define BIOLOGY  
biology.F
```

- Un modelo NPZD (5 componentes)

```
define BIO_NCh1PZD  
bio_NCh1PZD.F  
(+ oxígeno)
```

- Un modelo N2PZD2 (7 componentes)

```
define BIO_N2Ch1PZD2  
bio_N2Ch1PZD2.F  
(+ oxígeno)
```

- Un modelo llamado BioEBUS (13 componentes)  
(Eastern Boundary Upwelling Systems)  
basado en el nitrógeno, como moneda de intercambio.

```
define BIO_BioEBUS  
bio_BioEBUS.F  
(+ oxígeno)
```

- Un modelo llamado PISCES (24 componentes)  
(Pelagic Interactions Scheme for Carbon and Ecosystems Studies)  
basado en el carbono, como moneda de intercambio

```
define PISCES  
Un directorio completo
```

(PISCES → PISCES v2)

<https://www.pisces-community.org/>

## Archivos de Entrada

- Condiciones de Borde (CLM/BRY)

make\_clim\_npzd

make\_clim\_pisces

make\_clim\_bioebus

make\_bry\_npzd

make\_bry\_pisces

make\_bry\_bioebus

- Condiciones Iniciales

make\_ini\_npzd

make\_ini\_pisces

make\_ini\_bioebus

- Extras

make\_dust (Fe)

Nutrientes en ríos

## Variables Consideradas

- croco.in

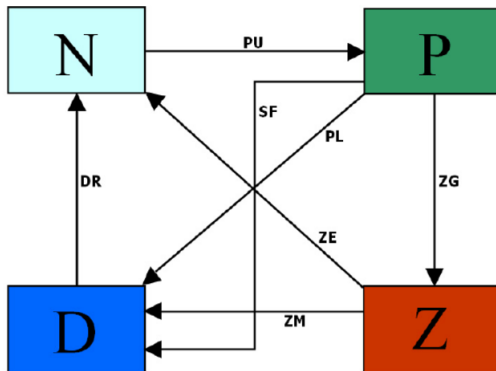
```
primary_history_fields: zeta UBAR VBAR U V wrtT(1:NT)
                        T T T T T 30*T
```

- Bioquímica de ríos

```
psource: Nsrc Isrc Jsrc Dsrc Qbar [m3/s] Lsrc T S
DIC Alkali O2 CaCO3 PO4 POC Si NPhy MiZoo Doc DPhy MeZoo
BSi Fe BFe GOC SFe DFe DSi NFe NChl DChl NO3 NH4 Tsrc
      28
288 274 0 -648 T T F F T F T F T T T F T
T F F F F F F F T T T T 9.8 0.1 0 0 325 0 0.214 0
118 0.117 0.047 0 0.273 0.109 0 0 0 0 0 0 0 0 0.234
0.546 1.86 0.74
```

# Biogeoquímica

NPChZD



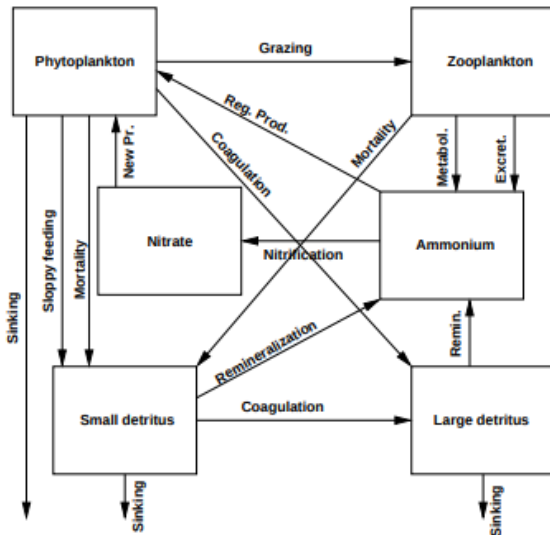
**PU** - Phytoplankton uptake  
**ZG** - Zooplankton grazing  
**ZM** - Zooplankton mortality  
**DR** - Detritus remineralization

**PL** - Phytoplankton lysis  
**ZE** - Zooplankton excretion  
**SF** - Sloppy feeding



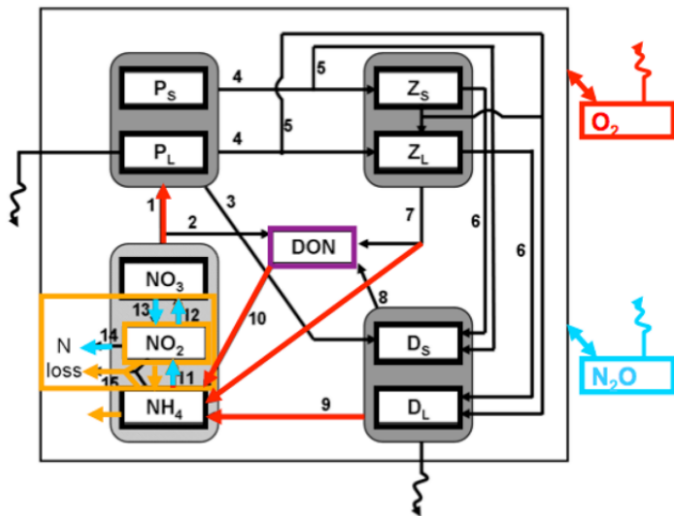
# Biogeoquímica

N2PChZD2



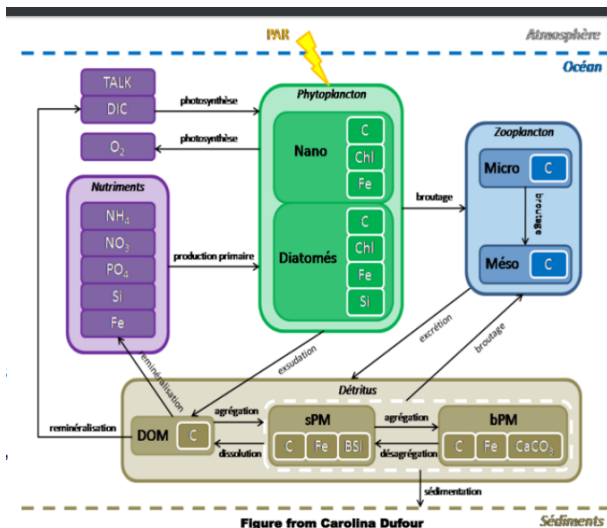
# Biogeoquímica

BioEBUS



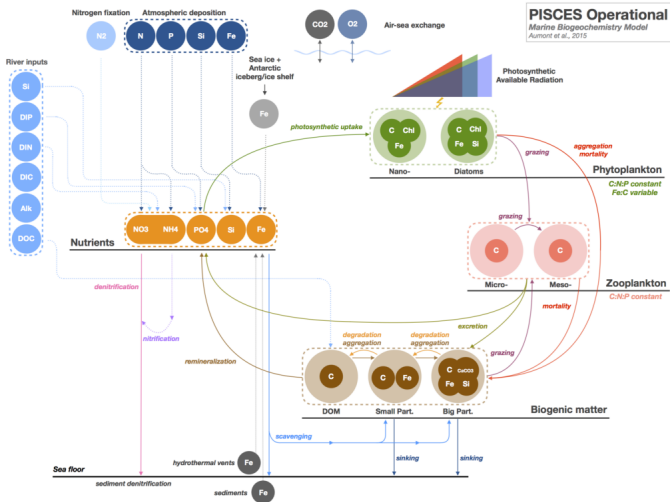
# Biogeoquímica

PISCES



# Biogeoquímica

PISCES



# Biogeoquímica

## Aspectos Prácticos

- Aumentan el tiempo de cálculo en 2-4 veces
- Técnicamente, pueden ser calculados *off-line*
- Pueden incluir aportes atmosféricos o de ríos
- Escasa información para validar
  - ▶ Color de Océano (SeaWiifs) Chl-a
  - ▶ WOA, CARS
  - ▶ Mediciones
- MUY escasa información sobre los parámetros que usan

# Biogeoquímica

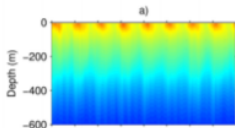
Validación BioEBUS

**Time series**

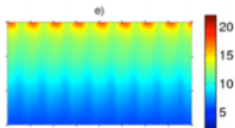
**22-24°S, 12.5-15°E**

Temperature  
(°C)

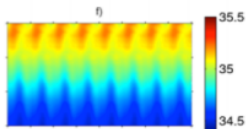
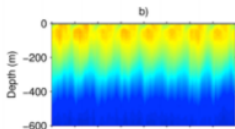
**ROMS/BioEBUS**



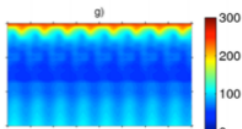
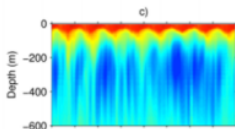
**CARS (2006, 2009)**



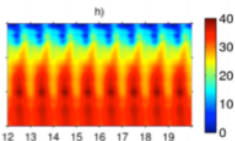
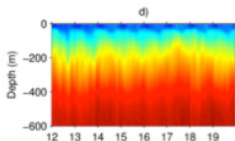
Salinity



Oxygen  
(mmol O<sub>2</sub> m<sup>-3</sup>)

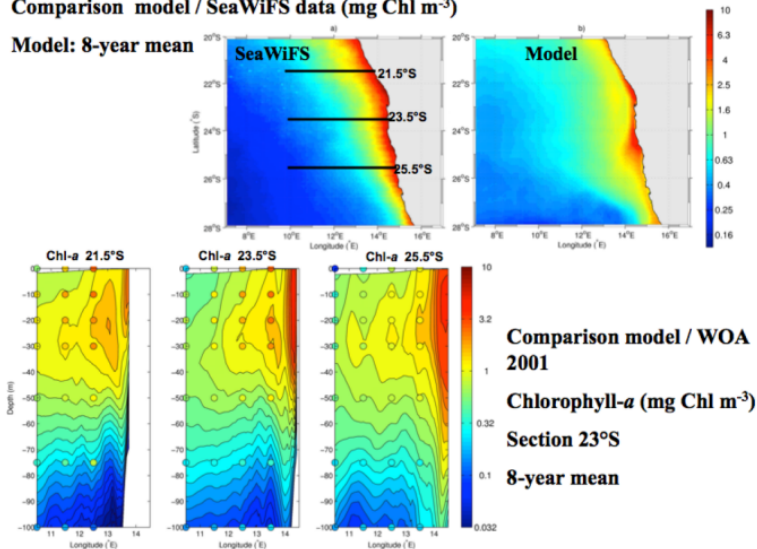


Nitrate  
(mmol N m<sup>-3</sup>)



### Comparison model / SeaWiFS data (mg Chl m<sup>-3</sup>)

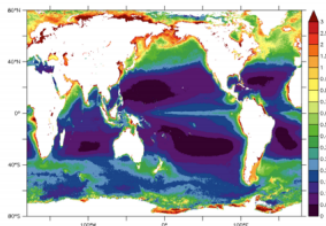
Model: 8-year mean



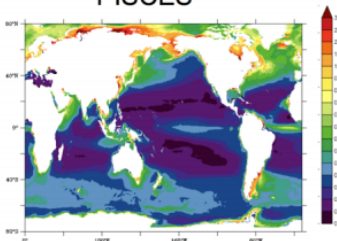
# Biogeoquímica

## Validación PISCES

Chlorophyll (mgChl/m<sup>3</sup>, annual mean)

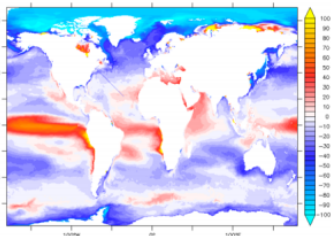
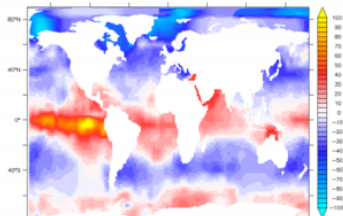


PISCES



SeaWifs

Takahashi et al.  
Delta pCO<sub>2</sub> (ppm, annual mean)





# Biogeoquímica

namelist\_pisces (v1.0)

Equation name	Code name	Description
<b>Phytoplankton</b>		
$\alpha^I$	pislope, pislope2	Initial slope of the PI curve
$\beta^I$	excret	Excretion of DOC
$K_{PO_4}^{I,min}$	concnh4, concndh4	Minimum half-saturation constant for Phosphate
$K_{NH_4}^{I,min}$	concnh4, concndh4	Minimum half-saturation constant for Ammonium
$K_{NO_3}^{I,min}$	concnno3, concndno3	Minimum half-saturation constant for Nitrate
$K_{Si}^1$	xks11	First parameter for Si/C
$K_{Si}^2$	xks12	Second parameter for Si/C
$K_{Fe}^{I,min}$	concnfer, concdfer	Minimum half-saturation constant for Iron
$S_{rat}^I$	xsizern, xsizerd	Size ratio of phytoplankton
$\theta_{Si,D}^{opt}$	grosip	Optimal Si/C uptake ratio of diatoms
$\theta_{Fe,I}^{opt}$	qnfelim, qdfelim	Optimal iron quota
$\theta_{max}^{opt}$	fecm, fedm	Maximum iron quota
$m^I$	sprat, sprat2	phytoplankton mortality rate
$w^P$	uch1	Minimum quadratic mortality of phytoplankton
$w_{max}^D$	uchld	Maximum quadratic mortality of diatoms
$K_m$	xsmort	Half-saturation constant for mortality
$\theta_{chl,max}$	chlcm, chlcm	Maximum Chl/C ratios of phytoplankton
$I_{max}$	xsizephy, xsizedia	Threshold concentration for size dependency
<b>Zooplankton</b>		
$c_{max}^I$	epsber, epsber2	Maximum growth efficiency of zooplankton
$\gamma^I$	sigal1, sigal2	Excretion as DOC
$\sigma^I$	unass1, unass2	Non-assimilated fraction
$g_{rat}^I$	grazrat, grazrat2	Maximum grazing rate
$K_G^I$	xkgraz, xkgraz2	Half-saturation constant for grazing
$g_{flux}^I$	grazflux	Flux feeding rate
$p_{p-7P}^I$	xpref2p, xprefp	Preferences for nanophytoplankton
$p_{p-7D}^I$	xpref2d, xprefc	Preferences for diatoms
$p_{POC-7POC}^I$	xpref2c, xprefpoc	Preferences for POC
$p_z^I$	xprefz	Preference for microzooplankton
$F_{thresh}^I$	xthresh, xthresh2	Food threshold for zooplankton
$F_{thresh}^M$	xthreshphy,	Nanophytoplankton threshold for zooplankton
	xthresh2phy	
$D_{thresh}^I$	xthreshdia,	Diatoms threshold for zooplankton
	xthresh2dia	
$POC_{thresh}^I$	xthreshpoc,	POC threshold for zooplankton
	xthresh2poc	
$Z_{thresh}^M$	xthresh2zoo	Microzooplankton threshold for mesozooplankton
$m^I$	mzrat, mzrat2	Mesozooplankton mortality
$r^I$	resrat, resrat2	Excretion rate

# Biogeoquímica

namelist\_pisces

Equation name	Code name	Description
$\nu^f$	part, part2	Fraction of calcite that does not dissolve in guts
$\theta^{Fe,Zoo}$	ferat3	Fe/C ratio of zooplankton
<b>Organic matter</b>		
$\lambda_{DOC}$	xremik	Remineralization rate of DOC
$K_{DOC}$	xkdoc	Half-saturation constant for DOC remin.
$K_{Fe}^{fast}$	concbfe	Fe half-saturation constant for DOC remin.
$\lambda_{POC}$	xremip	Degradation rate of POC
$w_{POC}$	wsbio	Sinking speed of POC
$w_{GOC}^{min}$	wsbio2	Minimum sinking speed of GOC
$w_{dust}$	wdust	Sinking speed of dust
$\lambda_{Fe}$	xlami	Slope of scavenging rate of iron
$\lambda_{Fe}^{dust}$	xlandust	Scavenging rate of iron by dust
$\lambda_{CaCO_3}$	kdc	Dissolution rate of calcite
$nca$	nca	Exponent in the dissolution rate of calcite
$\lambda_{lab}^g$	xsilab	Proportion of the most labile phase in PSI
$\lambda_{PSi}^{stop}$	xsiremlab	Fast remineralization rate of PSI
$\lambda_{PSi}^{fast}$	xsirem	Slow remineralization rate of PSI
<b>Nutrients</b>		
$\lambda_{NH_4}$	nitrif	Maximum nitrification rate
$O_2^{min,1}$	oxymin	Half saturation constant for denitrification
$L_T$	ligand	Total ligand concentration
$N_{fix}^m$	nitrfix	Maximum rate of nitrogen fixation
$K_{Fe}^{fast}$	concfediaz	Fe half-saturation constant of nitrogen fixation
$E_{fix}$	diazolight	Photosynthetic parameter of nitrogen fixation
$Fe_{ice}$	icefeinput	Iron concentration in sea ice
$Fe_{sed}^{total}$	sedfeinput	Maximum sediment flux of iron
$Sol_{Fe}$	dustsolub	Solubility of iron in dust
<b>Stoichiometric ratios</b>		
$r_{CaCO_3}$	caco3r	Maximum rain ratio

≈ 100 parámetros + *hard-coded*

## Referencias

- PISCES

O. Aumont, C. Ethé, A. Tagliabue, L. Bopp, and M. Gehlen  
PISCES-v2: an ocean biogeochemical model for carbon and  
ecosystem studies *Geosci. Model Dev.*, 8, 2465–2513, 2015  
[www.geosci-model-dev.net/8/2465/2015/](http://www.geosci-model-dev.net/8/2465/2015/)

- BioEBUS

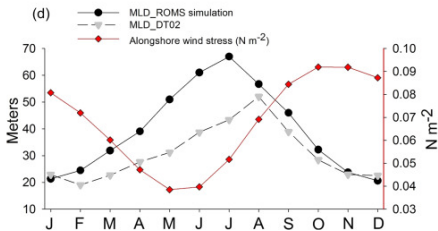
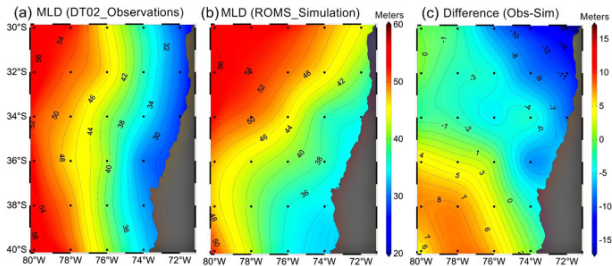
Gutknecht, E., Dadou, I., Le Vu, B., Cambon, G., Sudre, J.,  
Garçon, V., Machu, E., Rixen, T., Kock, A., Flohr, A.,  
Paulmier, A., and Lavik, G.: Coupled physical/biogeochemical  
modeling including O<sub>2</sub>-dependent processes in the Eastern  
Boundary Upwelling Systems: application in the Benguela,  
*Biogeosciences*, 10, 3559–3591, doi:10.5194/bg-10-3559-2013,  
2013.

### Chile

Vergara, O.A., Echevín, V., Sepúlveda, H.H. and Quiñones, R.A., 2017. Controlling factors of the seasonal variability of productivity in the southern Humboldt Current System (30-40° S): A biophysical modeling approach. *Continental Shelf Research*, 148, pp.89-103.

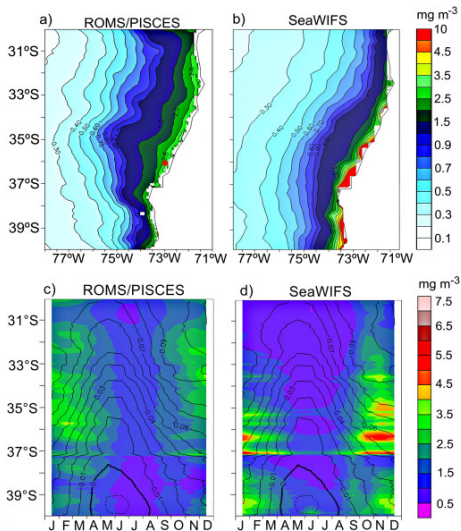
# Biogeoquímica

PISCES - Chile



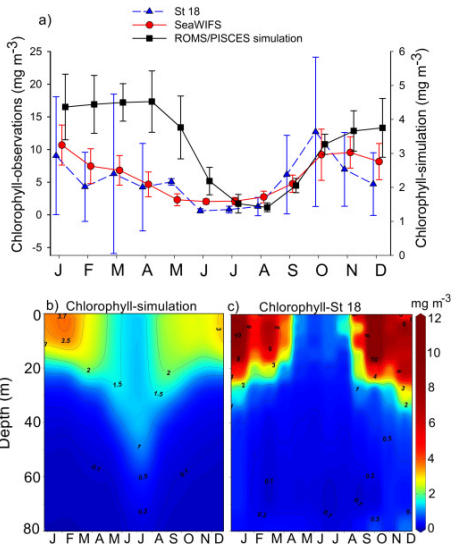
# Biogeoquímica

PISCES - Chile



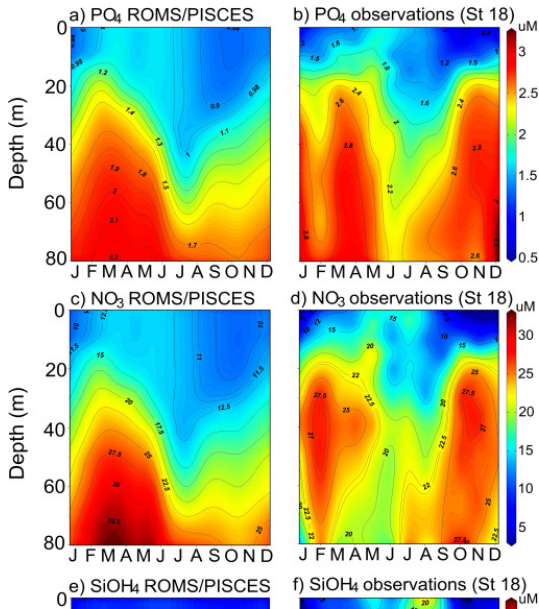
# Biogeoquímica

PISCES - Chile



# Biogeoquímica

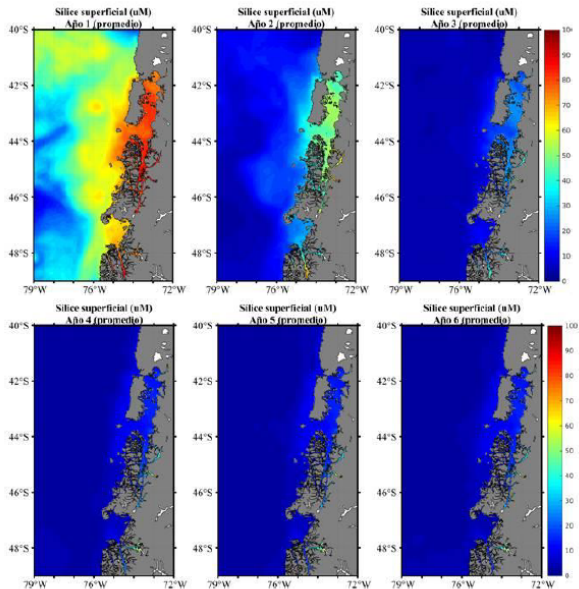
PISCES - Chile





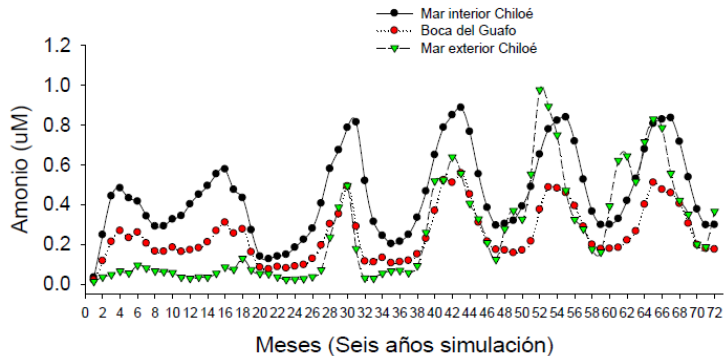
# Biogeoquímica

PISCES - Chile



# Biogeoquímica

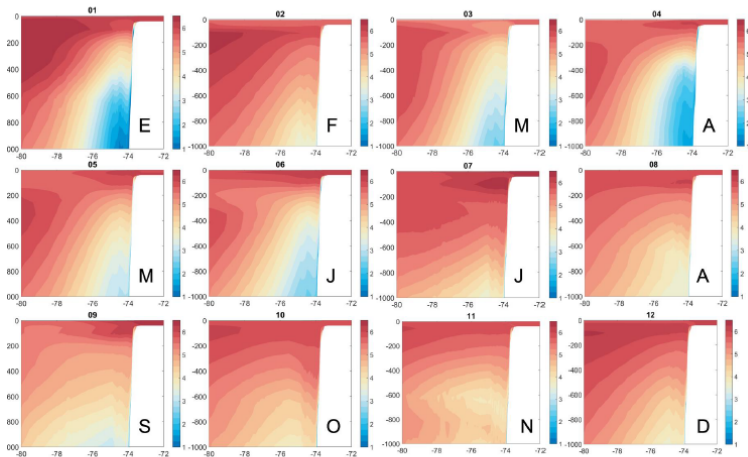
PISCES - Chile



# Biogeoquímica

PISCES - Chile

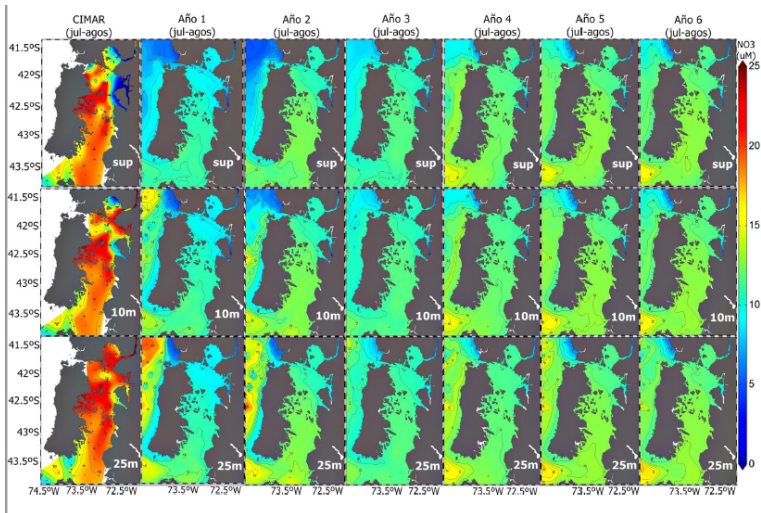
Oxígeno (ml/L) frontera norte, enero-diciembre



Oxígeno (ml/L) frontera norte MERCATOR-PISCES enero a diciembre (E-D).

# Biogeoquímica

PISCES - Chile



### Biogeoquímica 1D

Troupin, Charles, Pablo Sangrà, and Javier Arístegui. "Seasonal variability of the oceanic upper layer and its modulation of biological cycles in the Canary Island region." *Journal of Marine Systems* 80, 3-4 (2010): 172-183.