# ROMS-PISCES applications: Center-south (30º-40ºS) and Austral Chile

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# Controlling factors of the seasonal variability of productivity in the southern Humboldt Current System (30–40°S): A biophysical modeling approach

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# ROMS-PISCES characteristics

**Biogeochemical fields**
Nutrients
Oxygen
Dissolved inorganic carbon
Particulate organic carbon
Alkalinity

↓ *initial* *boundary*

**CARS**
CARS 2009 climatology (CSIRO Atlas of Regional Seas)

↓ *simulation* *15 years coupled*

**ROMS-PISCES**

↓ *climatology*

**10 years**

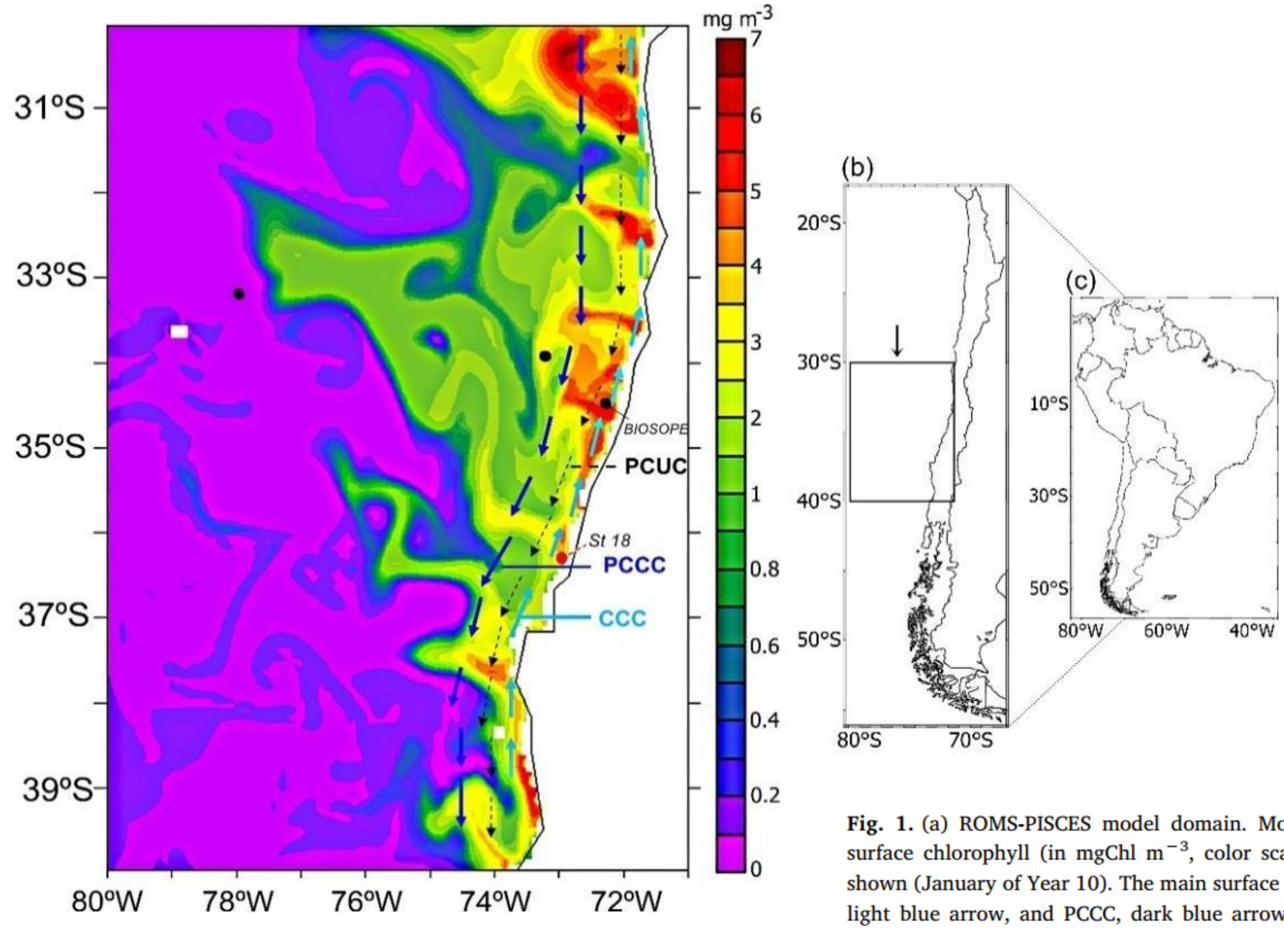



**Fig. 1.** (a) ROMS-PISCES model domain. Modeled surface chlorophyll (in mgChl $m^{-3}$, color scale) is shown (January of Year 10). The main surface (CCC, light blue arrow, and PCCC, dark blue arrow) and subsurface (PCUC, black dashed arrow) nearshore currents of the HCS are indicated. Station 18 is marked by a red dot, and the BIOSOPE stations for Fe measurements are denoted by black dots. (b) and (c) correspond to maps of Chile and South America, respectively. Rectangle in (b) indicates the location of the study area.

ROMS, grid configuration (Vergara et al., 2016)

# Light and nutrients co-limitation

**Potential limitation**

- Amonio
- Nitrato
- Hierro
- Silicato

### Light limitation:

$$L_{light} = 1 - e^{\left(-\alpha\left(\frac{Chl}{C}\right)*\frac{PAR}{\mu Lnut}\right)}$$

**α**= initial slope of **PI curve.**
**Chl/C=** chlorophyll/carbon ratio.
**PAR=** photosynthetically active radiation.
**μ=** growth rate temperature dependent.

*when sufficient light is available, this term reaches 1, and is less than 1 when light limits development

### Nutrient limitation:

$$L_{nut} = \min_{i=1\ldots n}\left[\left(\frac{C_i}{K_{i+C_i}}\right)\right]$$

**i=** nutrient (**$PO_4^{3-}$, $NO_3^-$, $NH_4^+$, Si, Fe**).
**Ci=** nutrient concentration.
**Ki=** mean saturation constant.

### "Limiting nutrient" is (i0) with the lowest ratio

$$\frac{C_{i0}}{K_{i0}+C_{i0}} < \frac{C_i}{K_{i+}C_i}$$

**Physical mechanisms of nutrient transport**

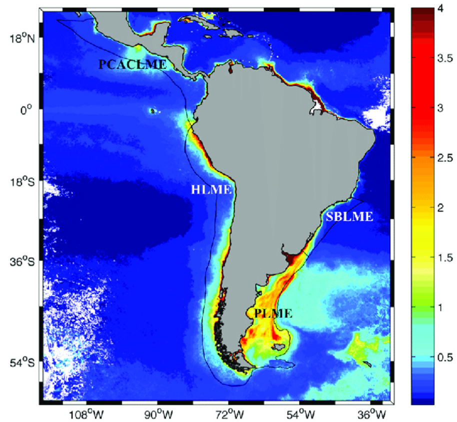
$$\frac{dC}{dt} = -\mu\partial xC - \upsilon\partial yC - \omega\partial zC + (\partial z(\kappa\partial zC))$$

**u=** zonal velocity.
**v=** meridional velocity.
**w=** vertical velocity.
**K=** vertical mixing.
**C=** nutrient concentration
**x, y, z**=coordinates, zonal, meridional y vertical.

# General assessments of simulation

## Surface chlorophyll (mg Chl m$^{-3}$)

**ROMS-PISCES**
-Nanophytoplankton + diatoms

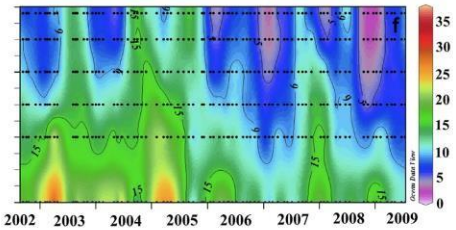



**SeaWIFS**
(Sea-Viewing Wide Field-of-View Sensor
-2000-2006

**Spatial** (30-40°S; 70-78°W) and **temporal** (100 km coastal band; annual cycle)

## Nutrients (PO4, NO3, SiOH4) y chlorophyll

**ROMS-PISCES**
-0-80 meters




**Station 18 (36.5°S; 73.1°W)**
-2004-2014
-0-80 meters

**Temporal** (annual cycle)

## Fe

**ROMS-PISCES**
-0-400 meters

“offshore” (33.36°S, 78°W)
“nearshore” (33.8°, 73.5°W)
"coastal“ (34.5°S; 72.4°W)

**BIOSOPE** cruise (Blain et al., 2008; Bonnet et al., 2008)
-0-400 meters

Fuente: Marrari et al. (2017), Anabalón et al. (2017)

# General assessments of simulation

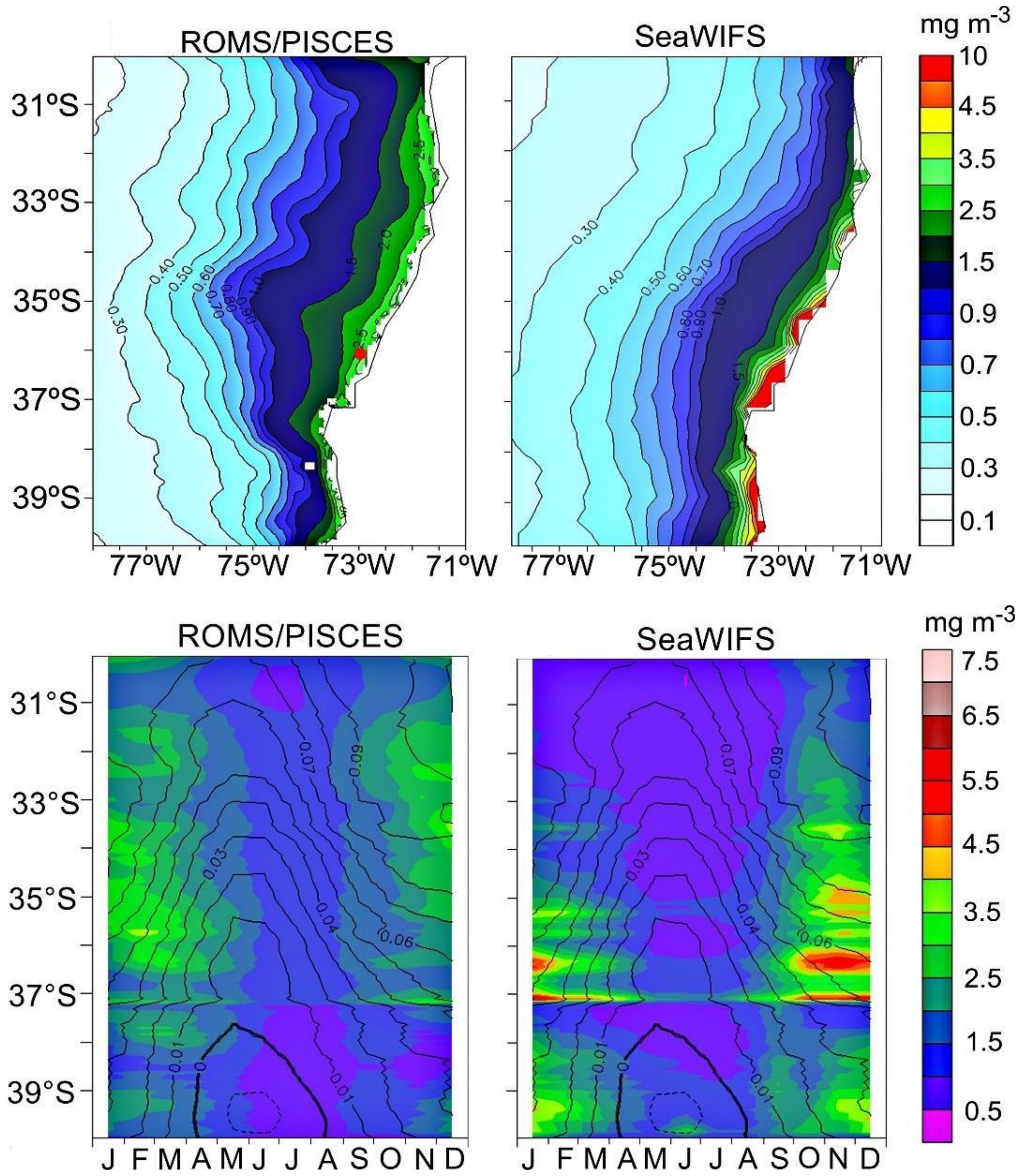



**Fig. 3.** Annual mean surface chlorophyll (in mg Chl-a $m^{-3}$) estimated by (a) the model (red circle: Station 18) and (b) SeaWIFS observations (1998–2006). Annual cycle of surface chlorophyll within a 100 km coastal band in (d) the model, and (e) SeaWIFS. Annual along-shore wind stress (in N $m^{-2}$) cycle is superimposed.

# General assessments of simualtion

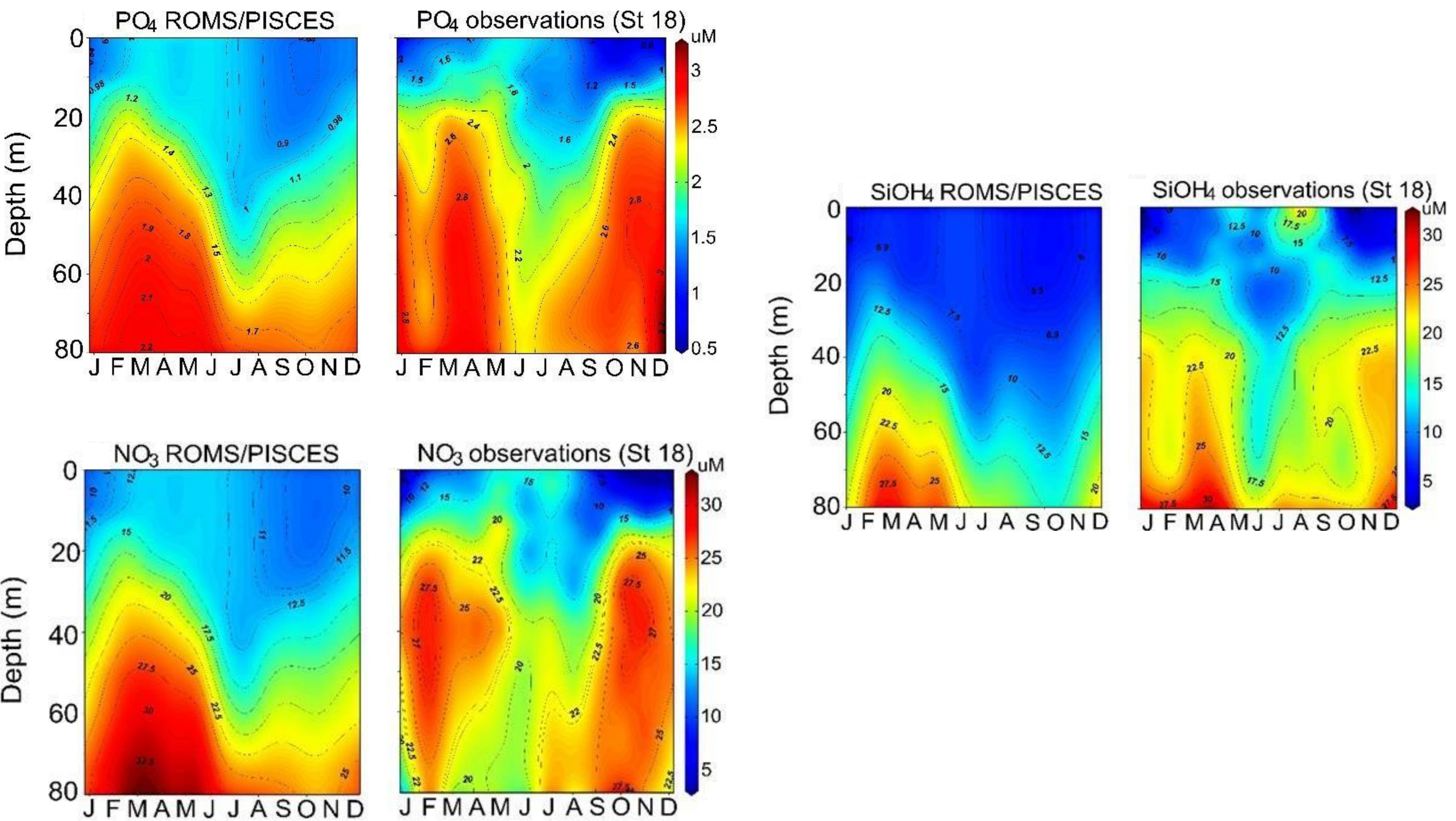



**Fig. 5.** Seasonal cycle of (a) Modeled phosphate, (c) nitrate and (e) silicate versus observed values (b, d, f) at Station 18. Units are $\mu mol\,l^{-1}$.

# Surface co-limitation

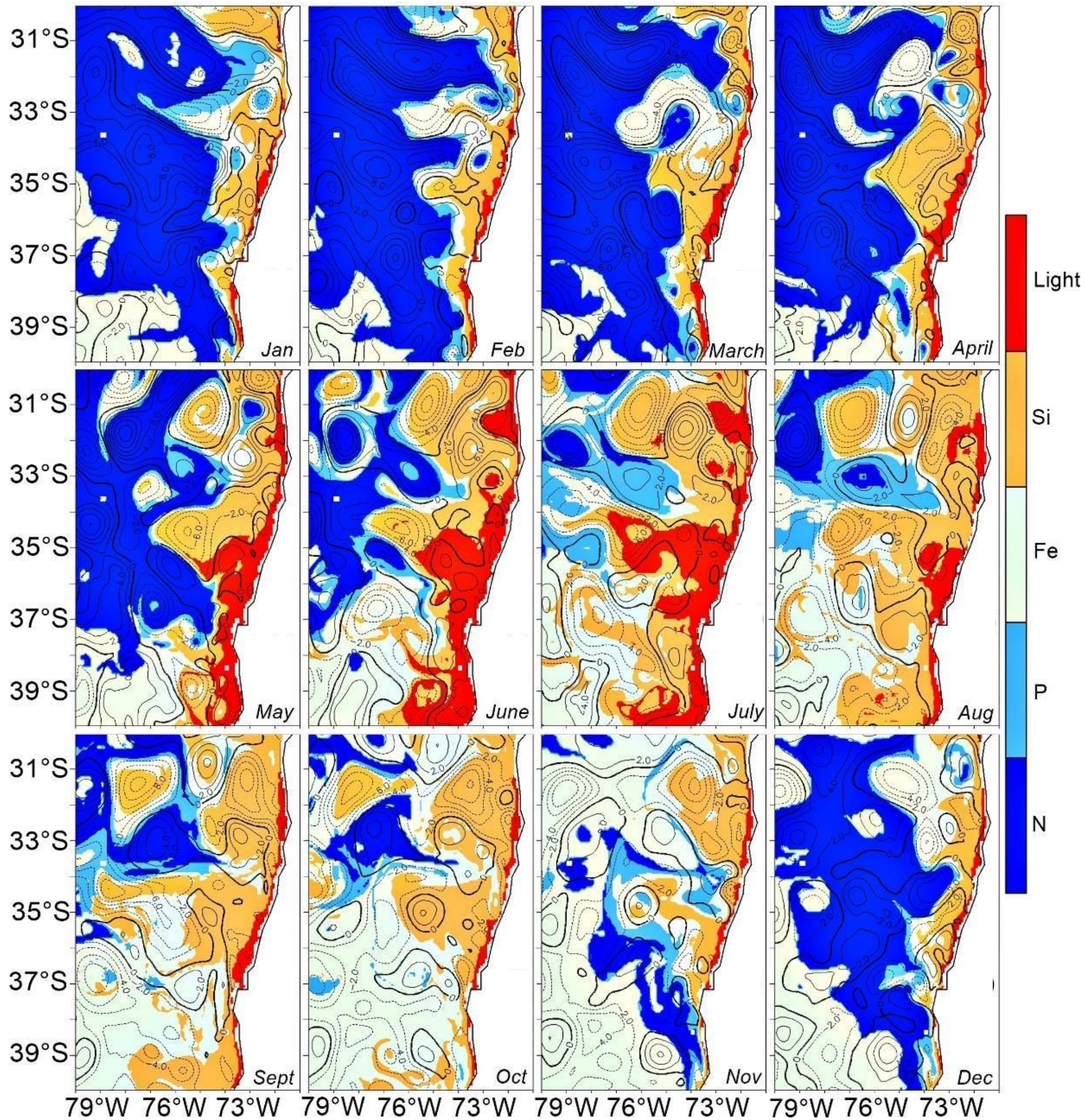



**Fig. 7.** Maps of surface co-limitation fields during Year 10, from January to December between 0–20 m. Colors indicate whether nutrients or light are limiting. Contours (in cm) represent the sea level anomaly.

# Dynamics of nutrients and phytoplankton in central-southern Chile

Co-limitation → **Phytoplankton = diatoms (70%)**

**Light**

***Autumn-winter***
Costal zone
(<100-200 km)

**Silicate**

***Summer-autumn***
Coastal zone
(<100-200 km)

**Nitrate**

***Summer-autumn***
Offshore (100-600 km)

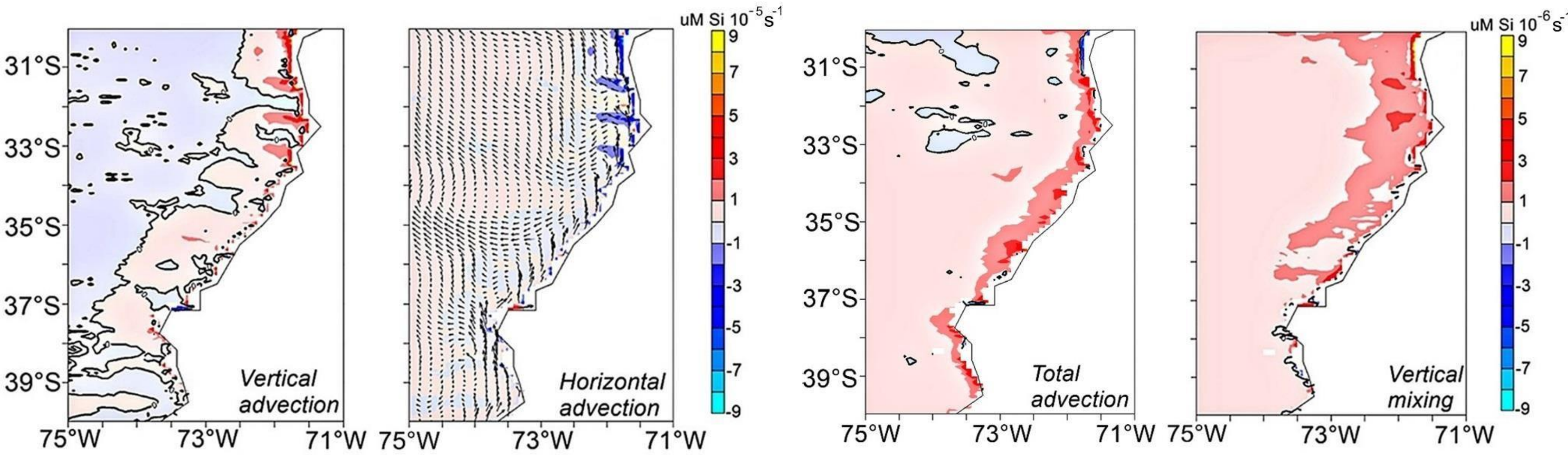
**Fe**

***Spring***
Offshore (100-600 km)

**Phosphate**

**Winter**
Offshore
(100-300 km, 30°-34°S)

# Dynamics of nutrients and phytoplankton in central-southern Chile




## Vertical advection

**30°-32°S** **33°-34°S**
**35°-36°S** **37°-38°S**

**Zonas de "surgencia"**
Punta Lengua de Vaca (30.24°S)
Curaumilla (33.1°S)
Punta Nugurne (35.9°S)
Punta Lavapié (37.15°S)

## Horizontal advection

Signature of **permanent mesoscale eddies and jets** between 30° and 35°S: while **vertical advection** brought nutrients to the coastal area, **Ekman currents and enhanced offshoreward jets** near 32°S, 33°S, 34°S transported part of the high coastal nutrient load offshore thus partly **compensating for the vertical input** associated with coastal upwelling.

## Total advection

Total positive advection predominated in the study area, with highest values (~ 3–5 10–6 μM Si s-1) at ~ 32°, 36° and 37°S.

## Vertical mixing

The input of nutrients through vertical mixing was positive everywhere, mainly between 30°S and 36°S.

# Dynamics of nutrients and phytoplankton in central-southern Chile

**Vertical advection** ⟷ **Horizontal advection**

balanced

compensated

**Vertical mix**

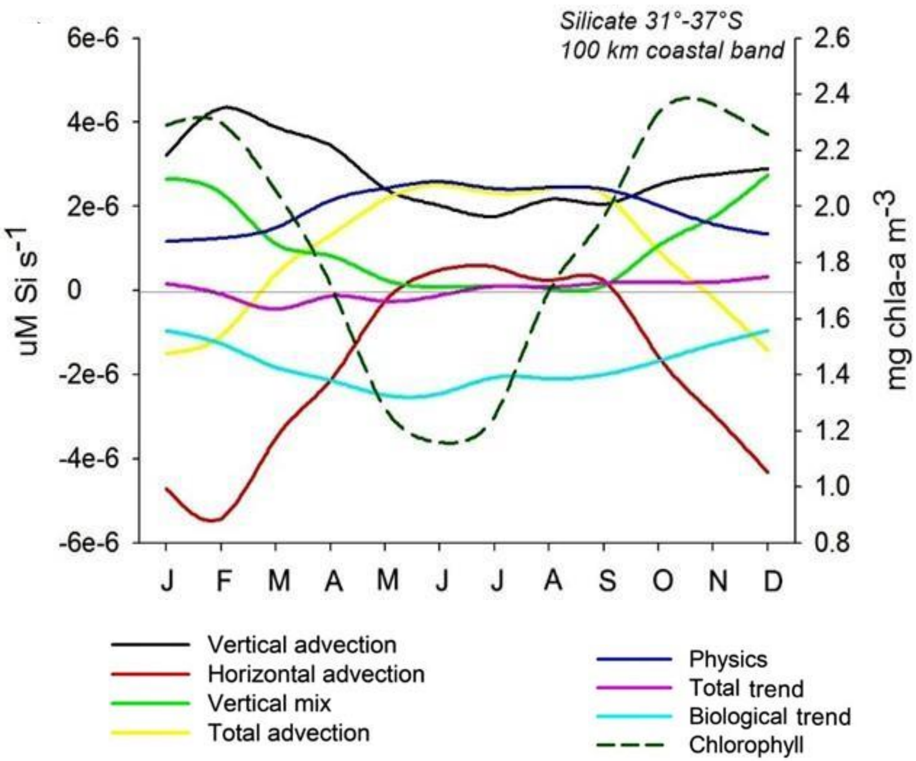
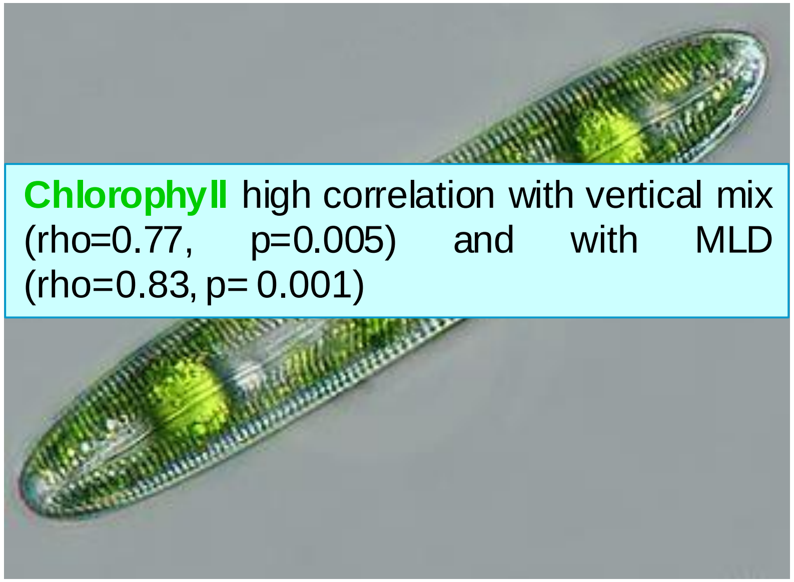



**Fig. 11.** Annual cycle of silicate transport terms within (a) a coastal band of 100 km, and (b) an offshore band of 100 km. Vertical advection (black), horizontal advection (red), total advection (yellow), vertical mixing (green), physical trend (blue), total trend (purple), biological trend (cyan). Surface chlorophyll (in mg Chl-a $m^{-3}$) is also shown (green dashed line). All fields are averaged between 0–20 m and 31° – 37°S.



**Chlorophyll** high correlation with vertical mix (rho=0.77, p=0.005) and with MLD (rho=0.83, p= 0.001)

## MOSA-ROMS (South-Austral Operational Model)

www.ifop.cl/chonos

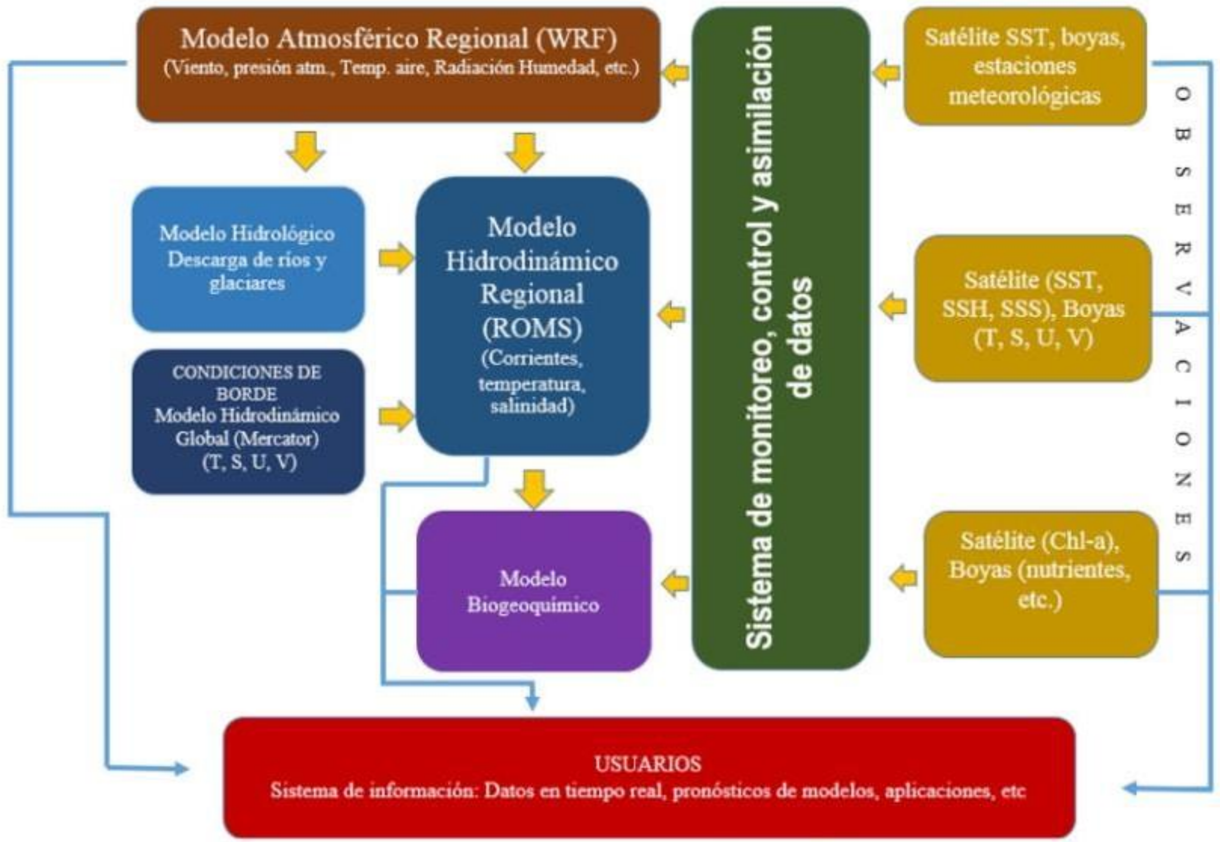



***Figura 1:*** *Modelo conceptual propuesto para el desarrollo a largo plazo del modelo operacional Sur-Austral, MOSA, el cual incluye todos los elementos contemplados en etapas futuras de desarrollo.*

**Informe Final**
Convenio de Desempeño 2019
Desarrollo de sistema de predicción sinóptico de circulación marina, VI Etapa.

**SUBSECRETARÍA DE ECONOMÍA Y EMT / Octubre 2020**

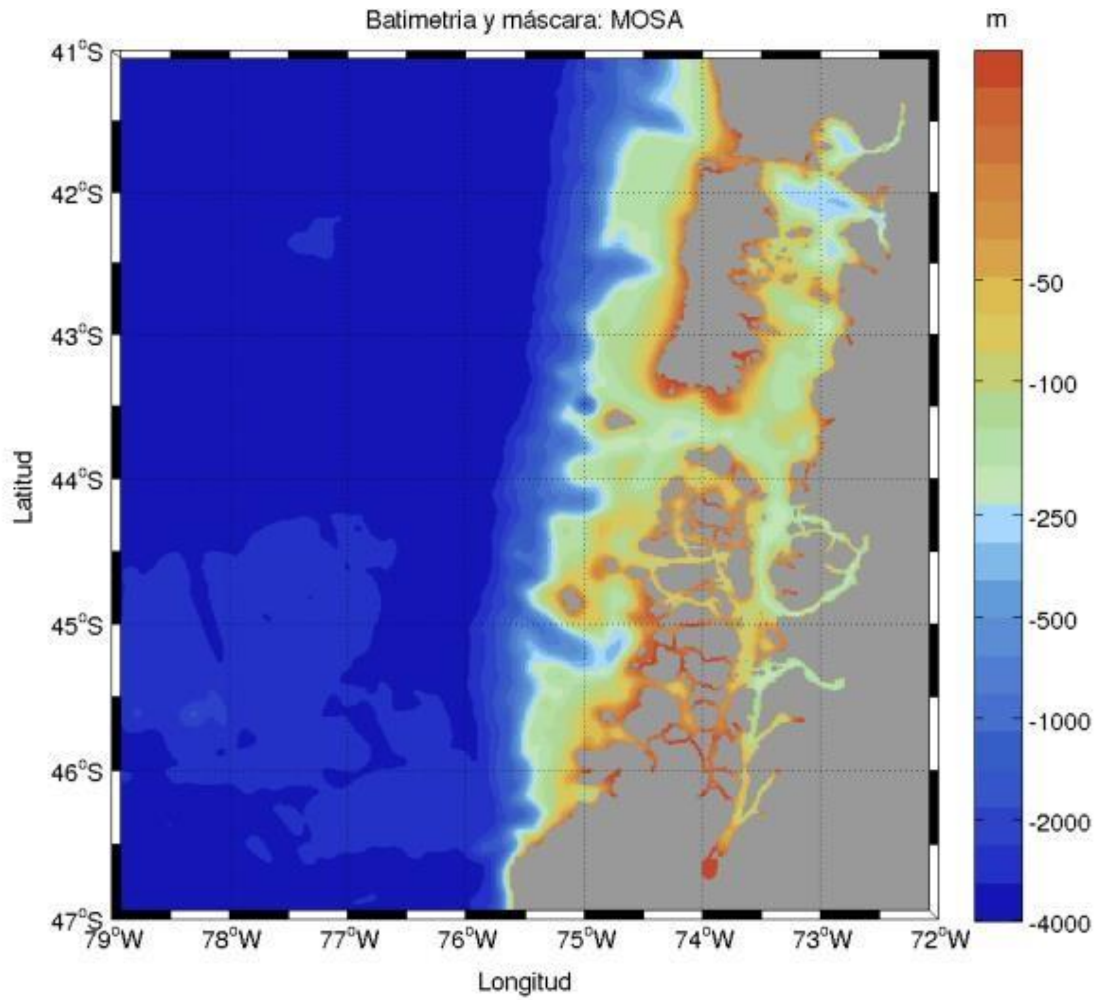
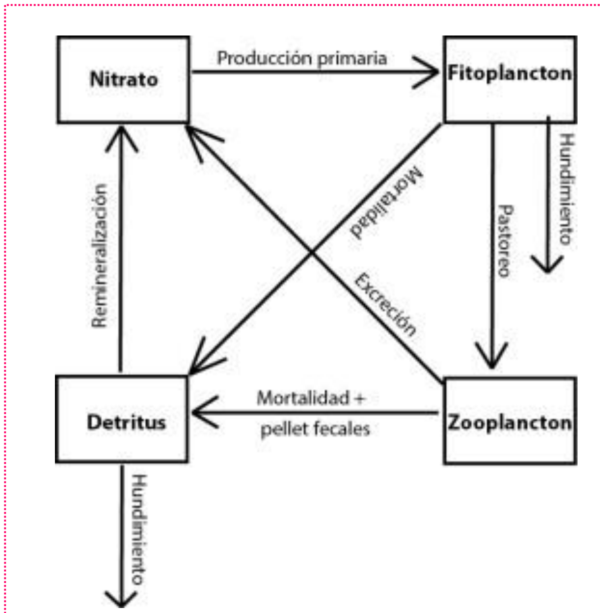


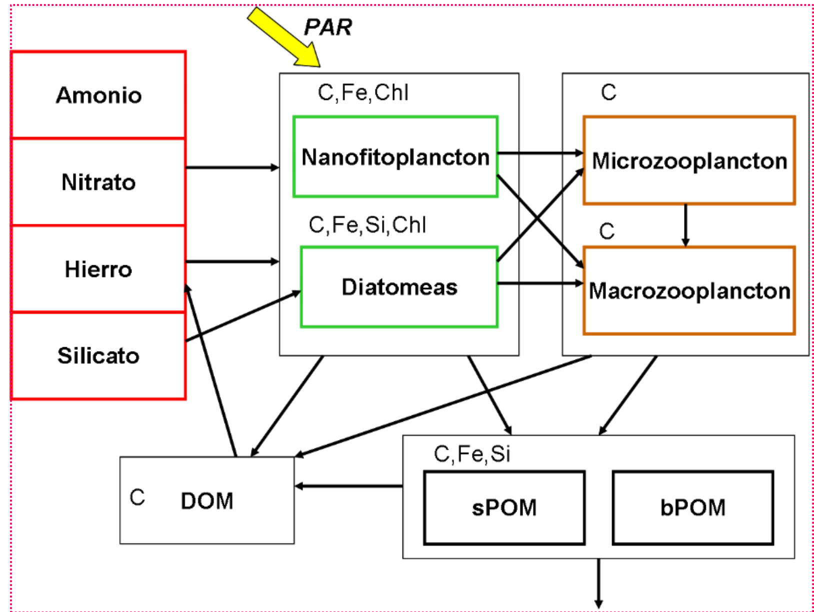

*Figura 3: Batimetría del modelo operacional MOSA-ROMS interpolada desde datos GEBCO y cartas náuticas digitales del SHOA*

**3.5 Metodología objetivo específico 5: Diagnosticar y diseñar un modelo biogeoquímico (BGQ) climatológico en el mar interior de Chiloé.**

## Modelo NPZD




## Modelo PISCES




Después de una revisión bibliográfica solo se encontraron 8 parámetros biogeoquímicos para Chile. Los otros parámetros fueron ajustados de la siguiente forma: 9 valores tomados del sistema de surgencia de Perú (Albert et al., 2010) y el resto a valores del trabajo de Kane et al. (2010), los cuales son valores estándar del modelo PISCES.

Los parámetros recopilados para las costas de Chile son los siguientes:

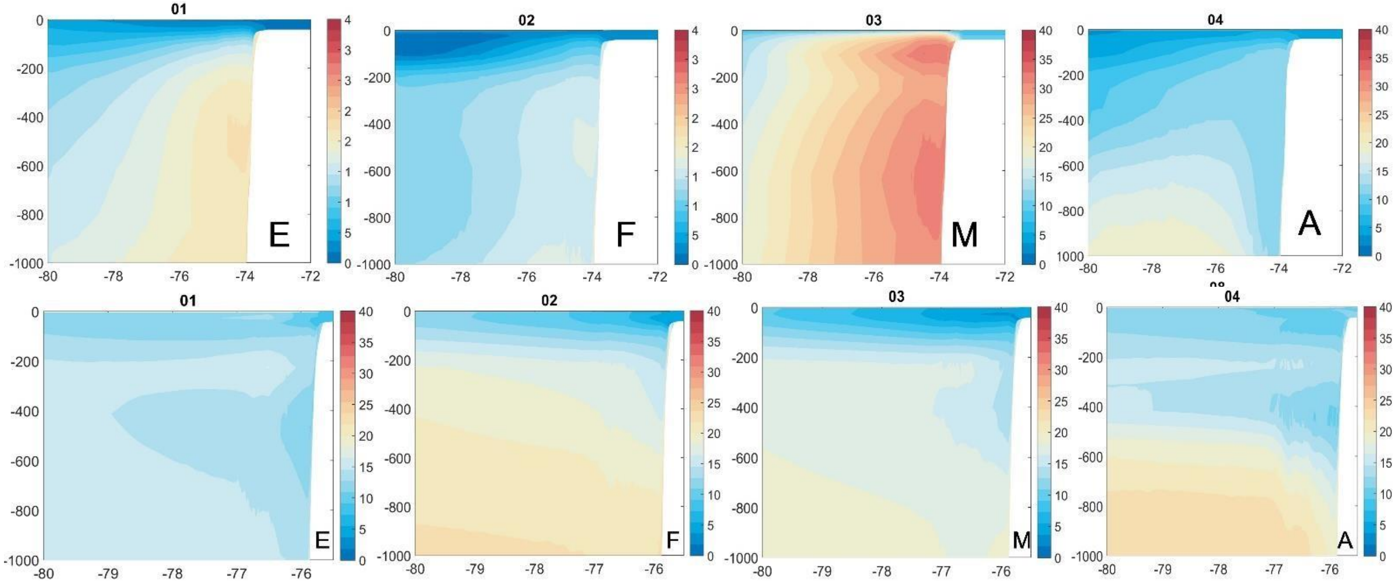
1. Máxima tasa de pastoreo del zooplancton (Bottjer y Morales, 2005).
2. Tasa de remineralización de carbono orgánico disuelto (Pantoja et al., 2004).
3. Tasa de remineralización del carbono orgánico particulado (Pantoja et al., 2006; Cuevas et al., 2004).
4. Tasa de exudación del mesozooplancton (Pérez-Aragón et al., 2011).
5. Tasa de mortalidad del zooplancton (Yáñez et al., 2012).
6. Tasa de nitrificación (Fernández y Farías., 2012).
7. Tasa de excreción de materia orgánica disuelta (González et al., 2007).

# MOSA-PISCES: boundary conditions: WOA-PISCES

**Nitrate (uM)**

North

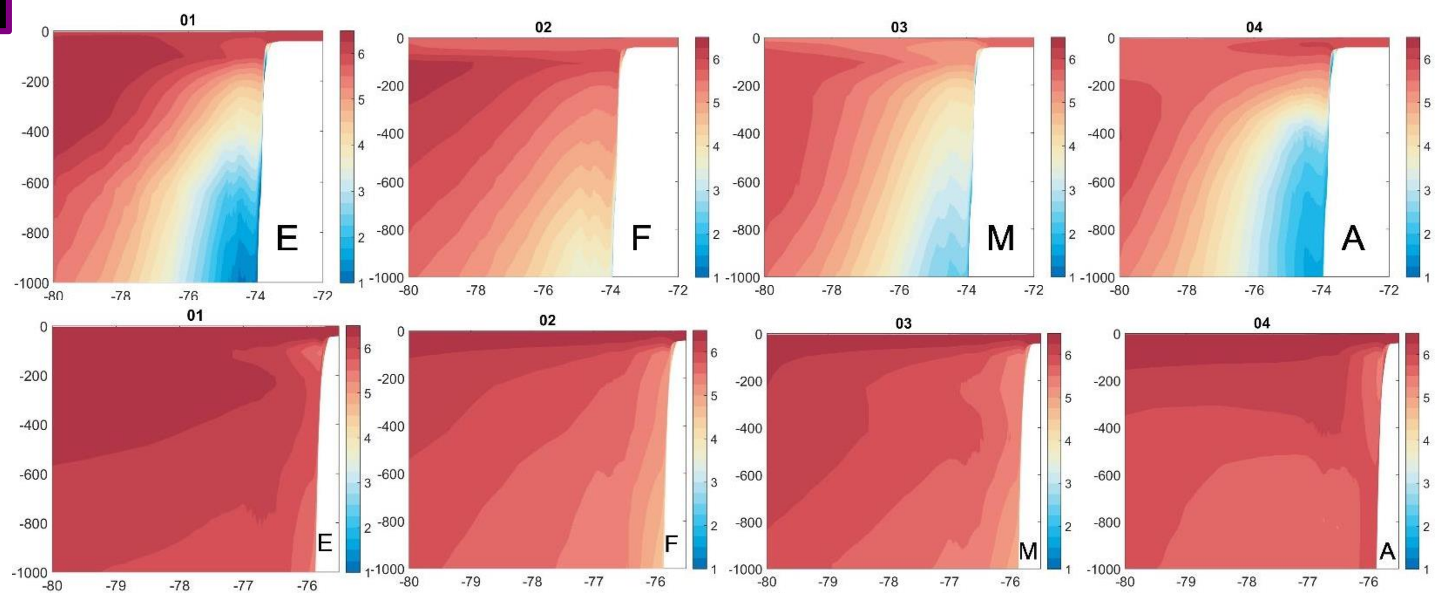
South



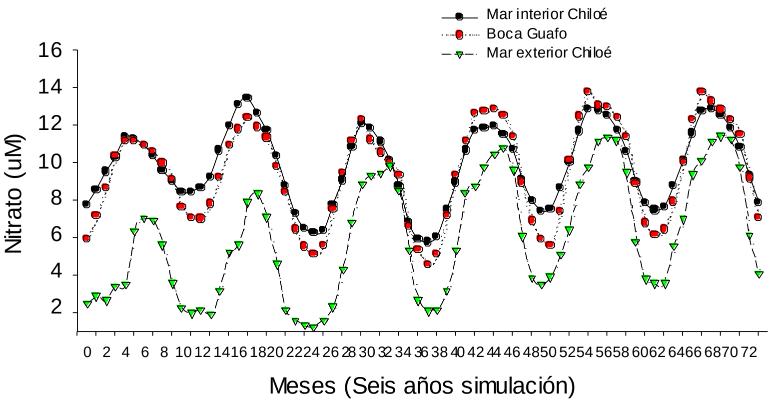

**Oxygen (ml/L)**

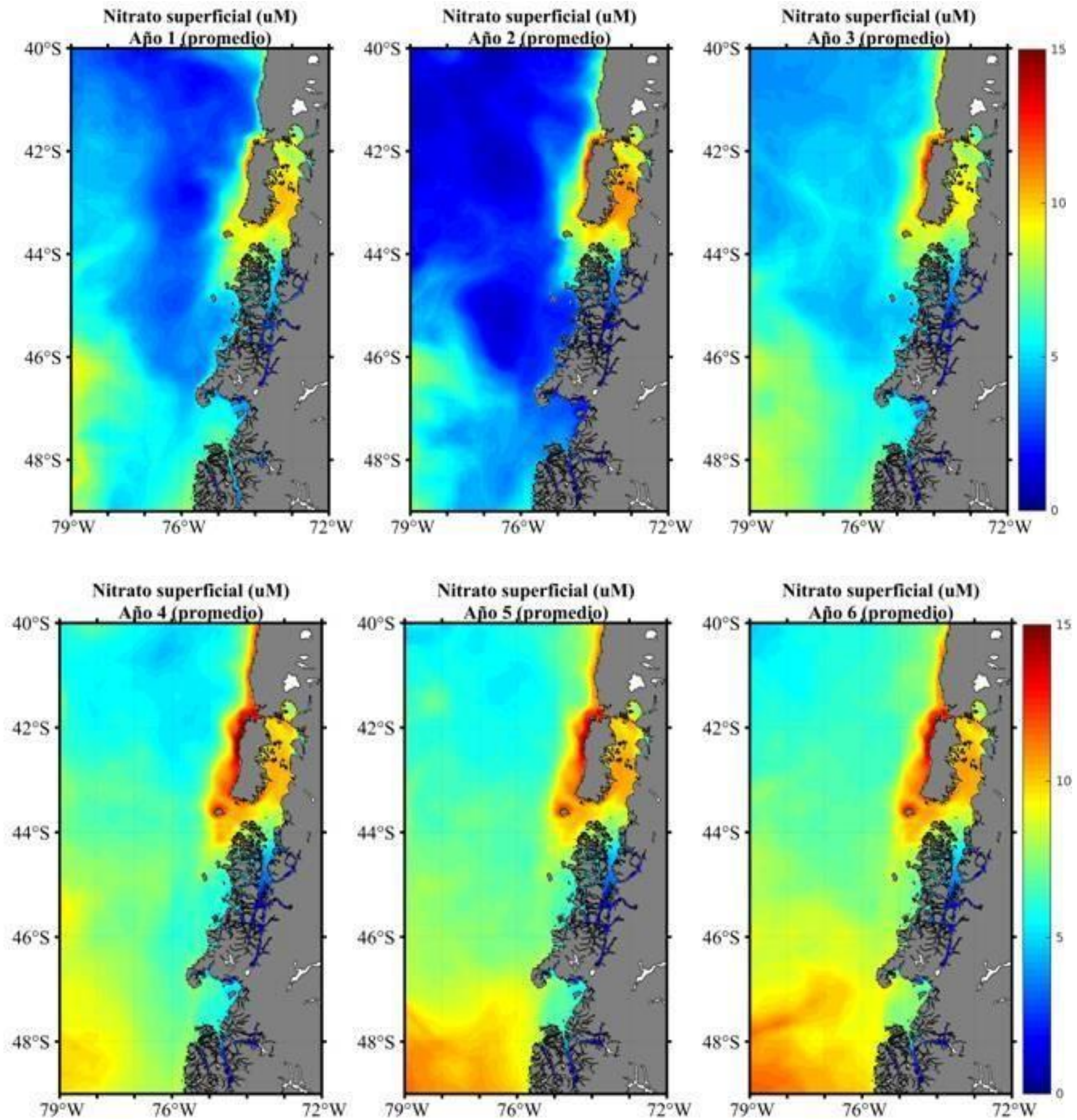
North

South

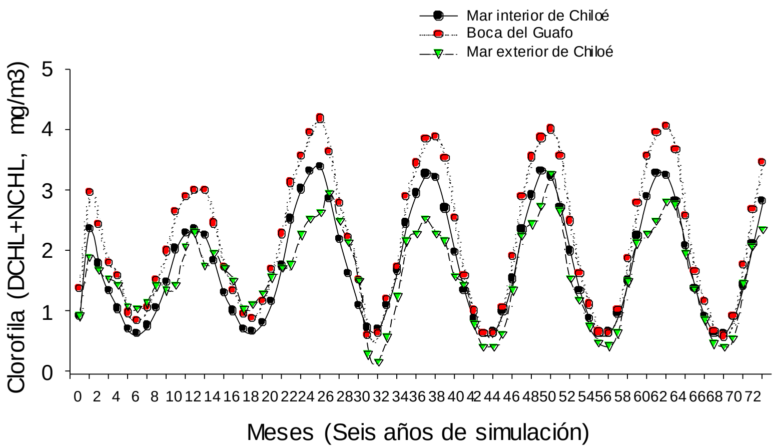


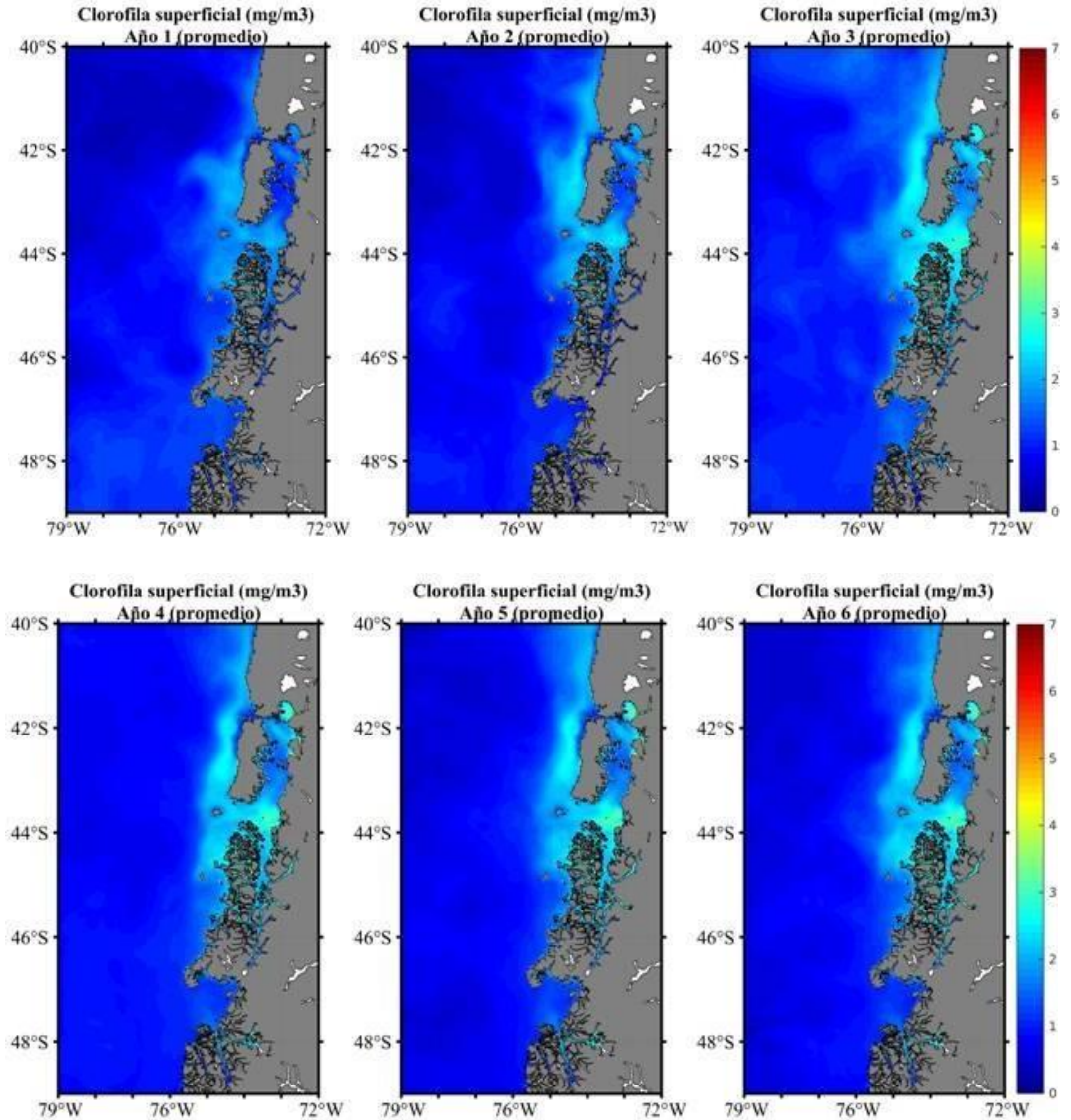
# MOSA-PISCES: Results

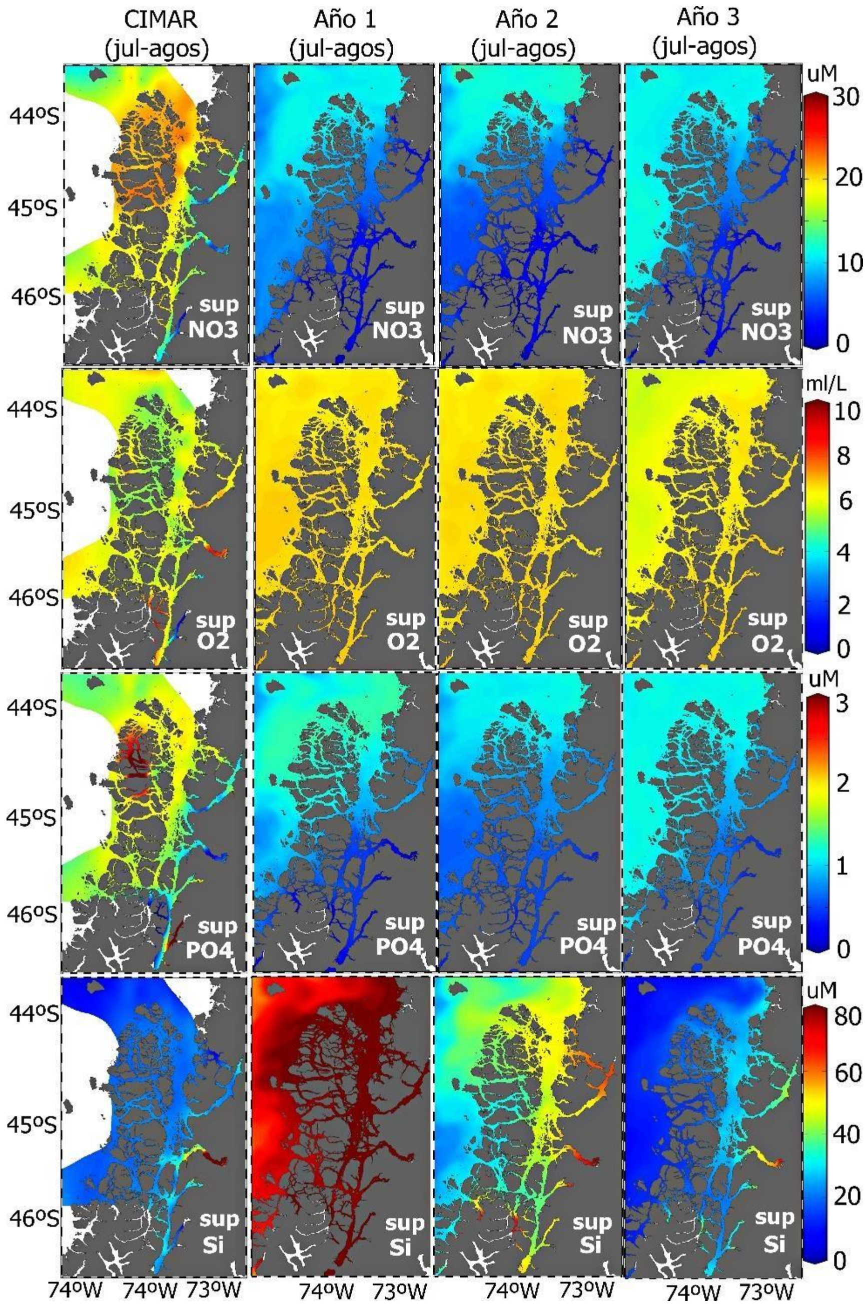


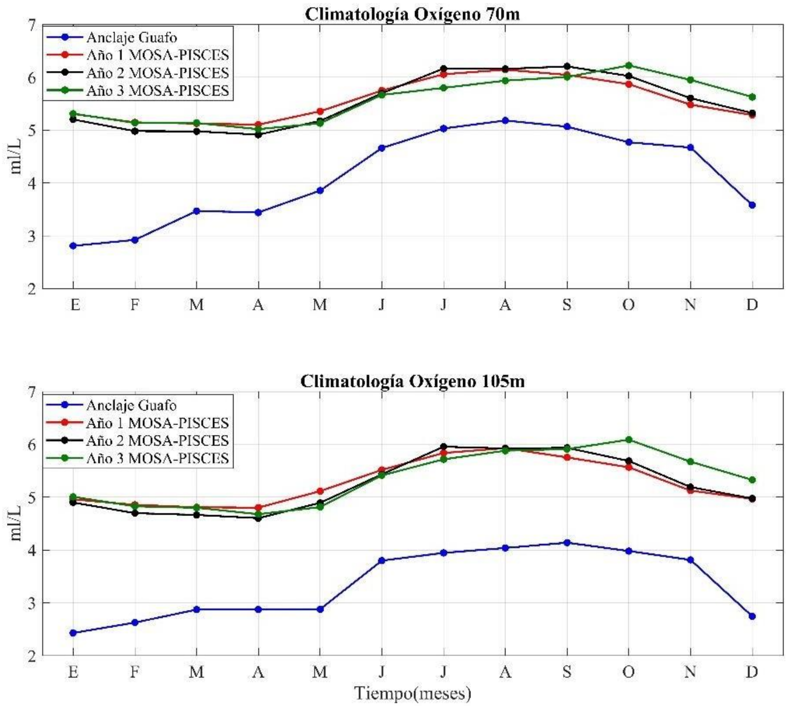



# MOSA-PISCES: Results




CIMAR
(jul-agos)
Año 1
(jul-agos)
Año 2
(jul-agos)
Año 3
(jul-agos)
uM
30
20
10
0
ml/L
10
8
6
4
2
0
uM
3
2
1
0
uM
80
60
40
20
0
44ºS
45ºS
46ºS
sup
NO3
sup
O2
sup
PO4
sup
Si
74ºW 74ºW 73ºW
74ºW 73ºW
74ºW 73ºW
74ºW 73ºW


Climatología Oxígeno 70m
Anclaje Guafo
Año 1 MOSA-PISCES
Año 2 MOSA-PISCES
Año 3 MOSA-PISCES
ml/L
E F M A M J J A S O N D
Climatología Oxígeno 105m
Anclaje Guafo
Año 1 MOSA-PISCES
Año 2 MOSA-PISCES
Año 3 MOSA-PISCES
ml/L
E F M A M J J A S O N D
Tiempo(meses)

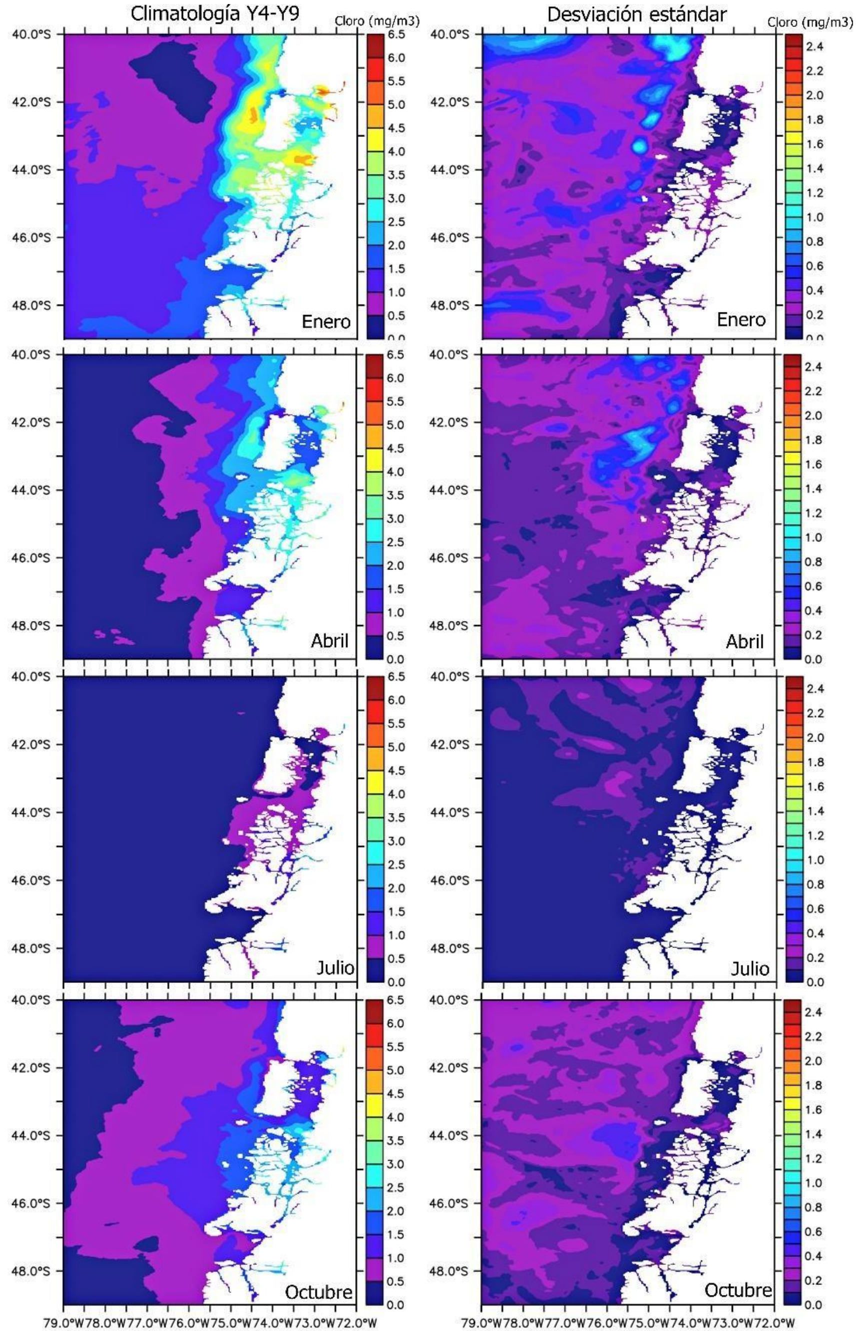
# MOSA-PISCES - Climatology

January

April

July

October



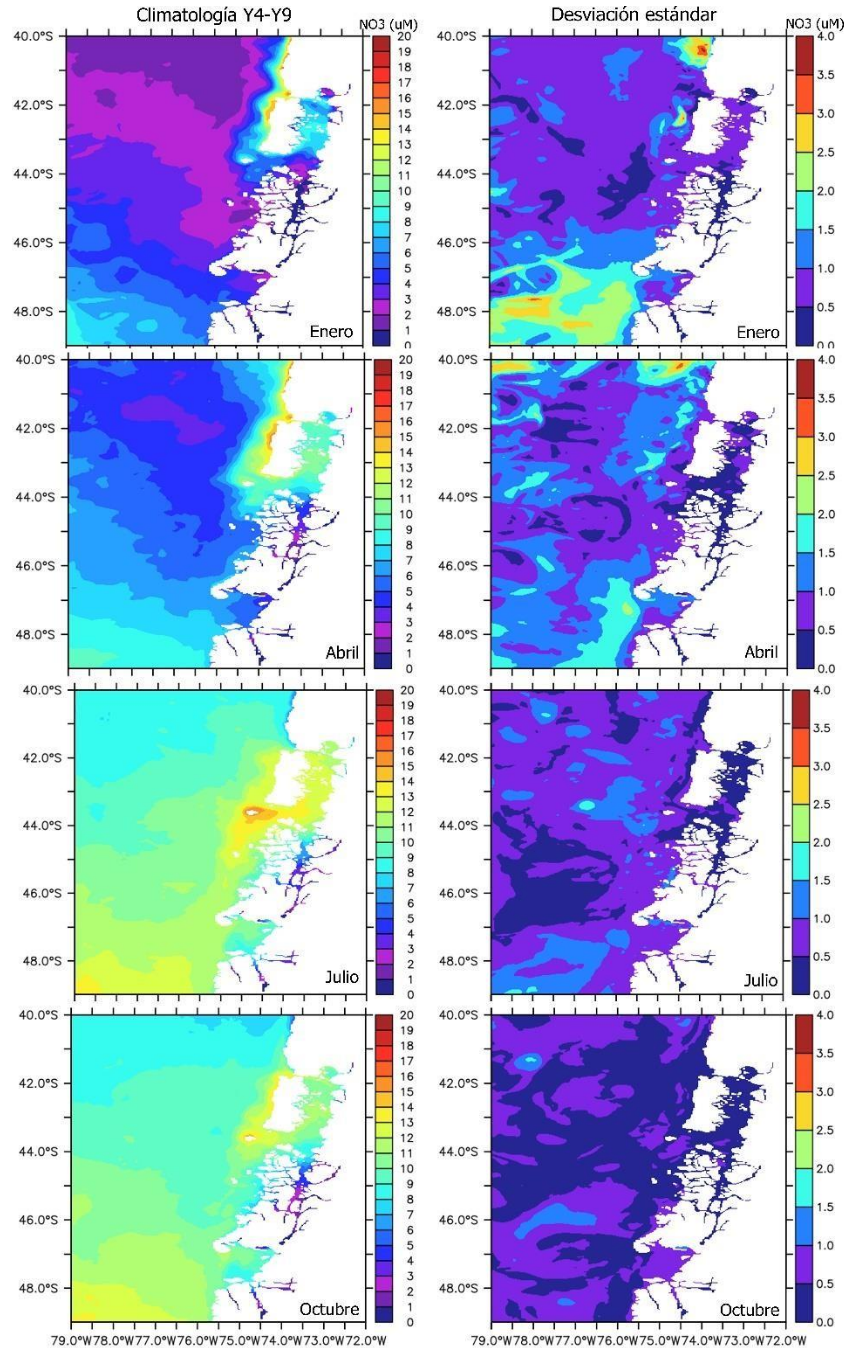
# MOSA-PISCES - Climatology

January

April

July

October



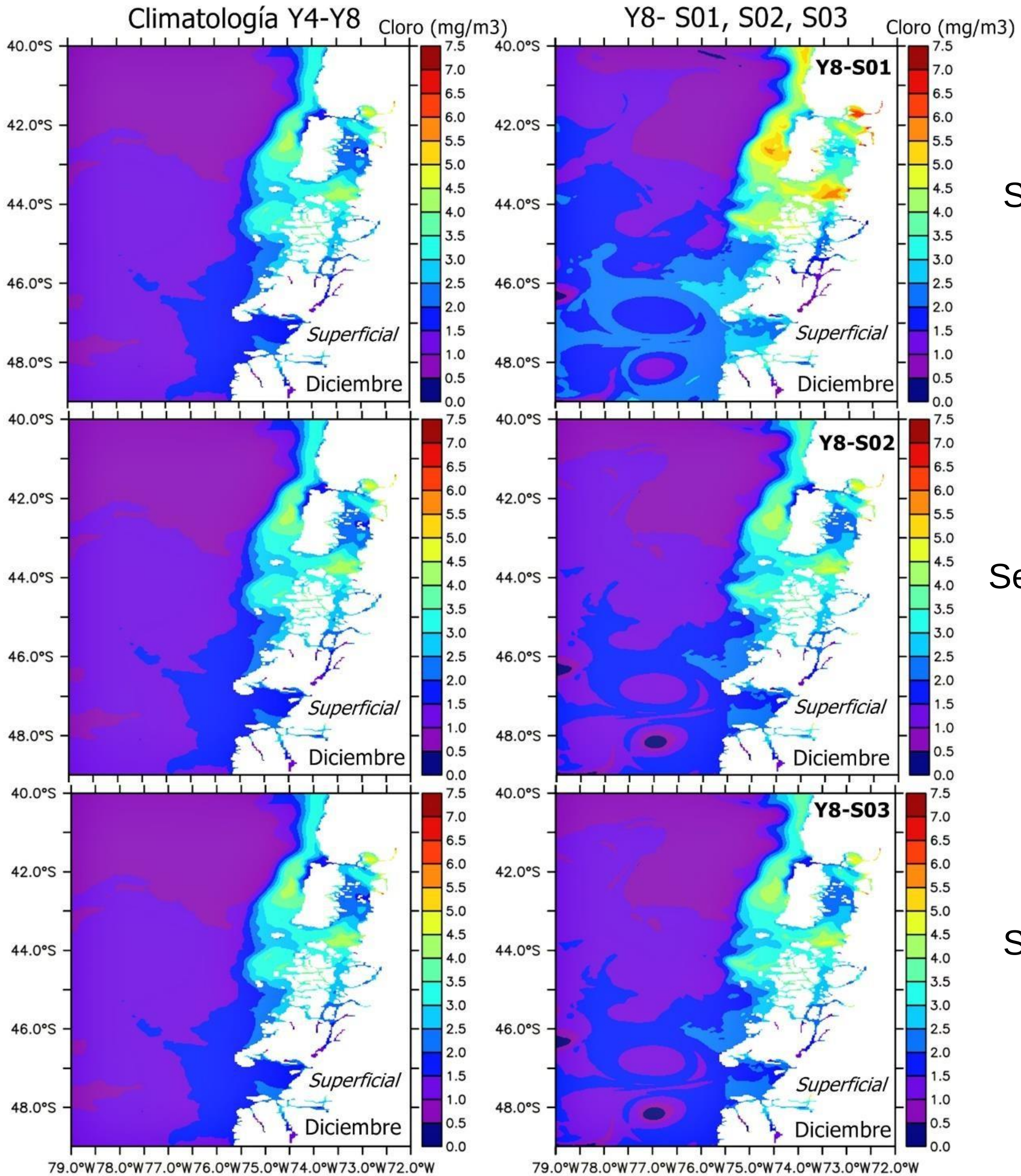
**Experiment S01**: Modification of parameters in the "namelist_pisces" to increase the concentration of chlorophyll and nitrate and decrease the concentration of oxygen.
The modified parameters are found in the nanophytoplankton, diatom, microzooplankton, mesozooplankton, nitrate, and oxygen equations, which are described in detail in Aumont et al. (2015).

| Actual value | Parameter in namelis | New value | Modification percentage | Relative to original namelist |
|---|---|---|---|---|
| 4 | grazrat | 3 | 25% | Decreases |
| 0.7 | grazrat2 | 0.525 | 25% | Decreases |
| 0.1 | excret | 0.05 | 50% | Decreases |
| 0.1 | excret 2 | 0.05 | 50% | Decreases |
| 0.01 | wchl | 0.0075 | 25% | Decreases |
| 0.02 | wchld | 0.015 | 25% | Decreases |
| 0.03 | mprat | 0.015 | 50% | Decreases |
| 0.03 | mprat2 | 0.015 | 50% | Decreases |
| 0.025 | nitrif | 0.05 | 100% | Increases |
| 0.153 | xremik | 0.306 | 100% | Increases |
| 1.2 | xremip | 0.24 | 80% | Decreases |
| 0.004 | mzrat | 0.006 | 50% | Increases |
| 0.012 | mzrat2 | 0.024 | 100% | Increases |

**Experiment S02**: Rivers nutrients concentration were increased by 50% this to increasing their flow towards Mar interior de Chiloé and surrounding areas.

**Experiment S03:** Through this experiment, the concentration of oxygen in the north boundary was reduced by 50%, to observe a reduced concentration in the south

## MOSA-PISCES Results- sensivity experiments

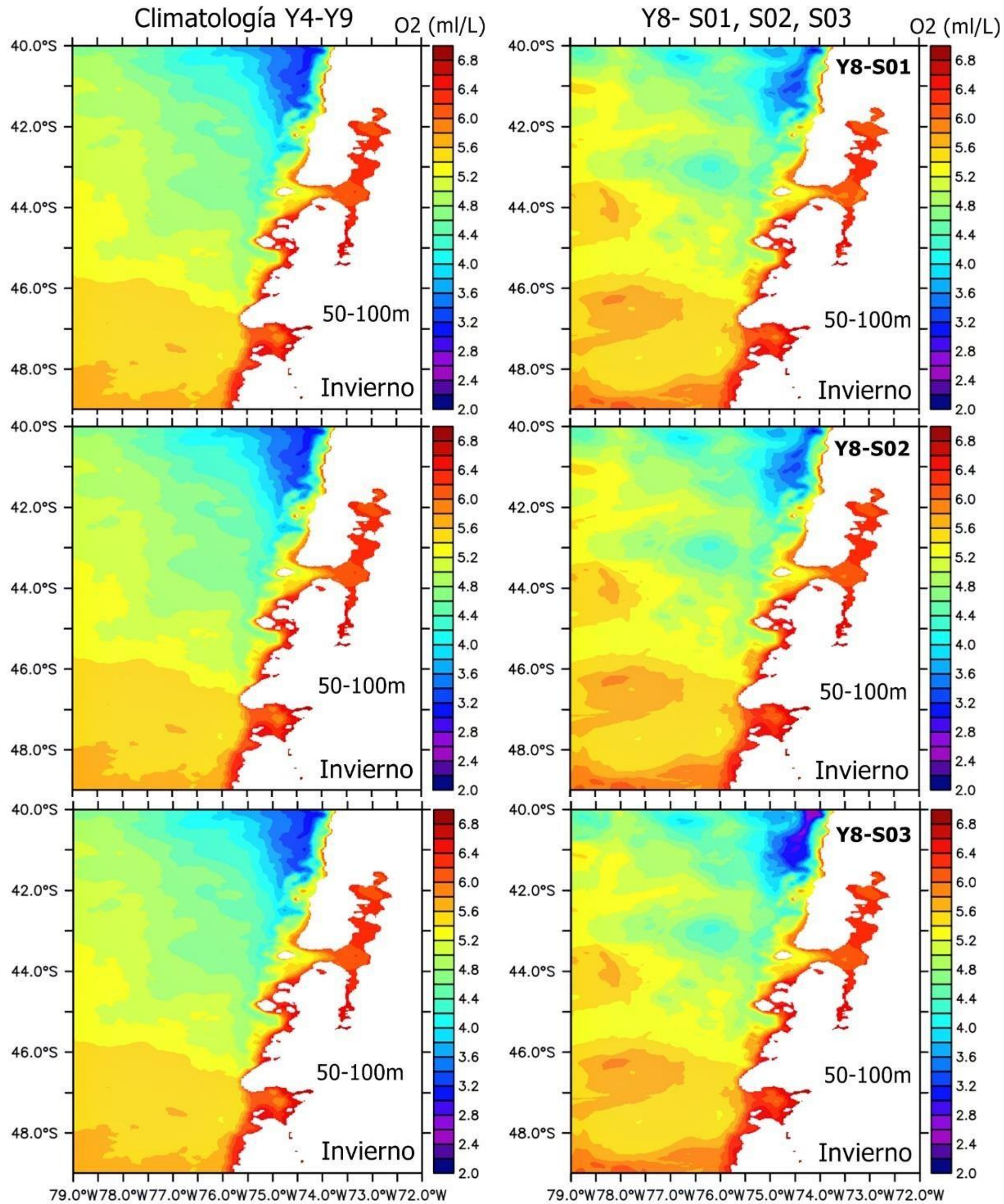



Sensivity S01

Sensivity S02

Sensivity S03

## MOSA-PISCES Results- sensivity experiments




Sensivity S01

Sensivity S02

Sensivity S03

# Work in progress……….

## Interannual biophysical simulations in the central- southern Chilean region (35° 38°S) using a high-resolution- circulation model: impact of the river's freshwater discharge

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oddyale@gmail.com

Vergara O.[a,f], Echevin V.[b], Sobarzo, M.[a,c,f,g], Sepúlveda, H. H.[e], Castro, L.[d,f], Soto-Mendoza, S.[d,f]

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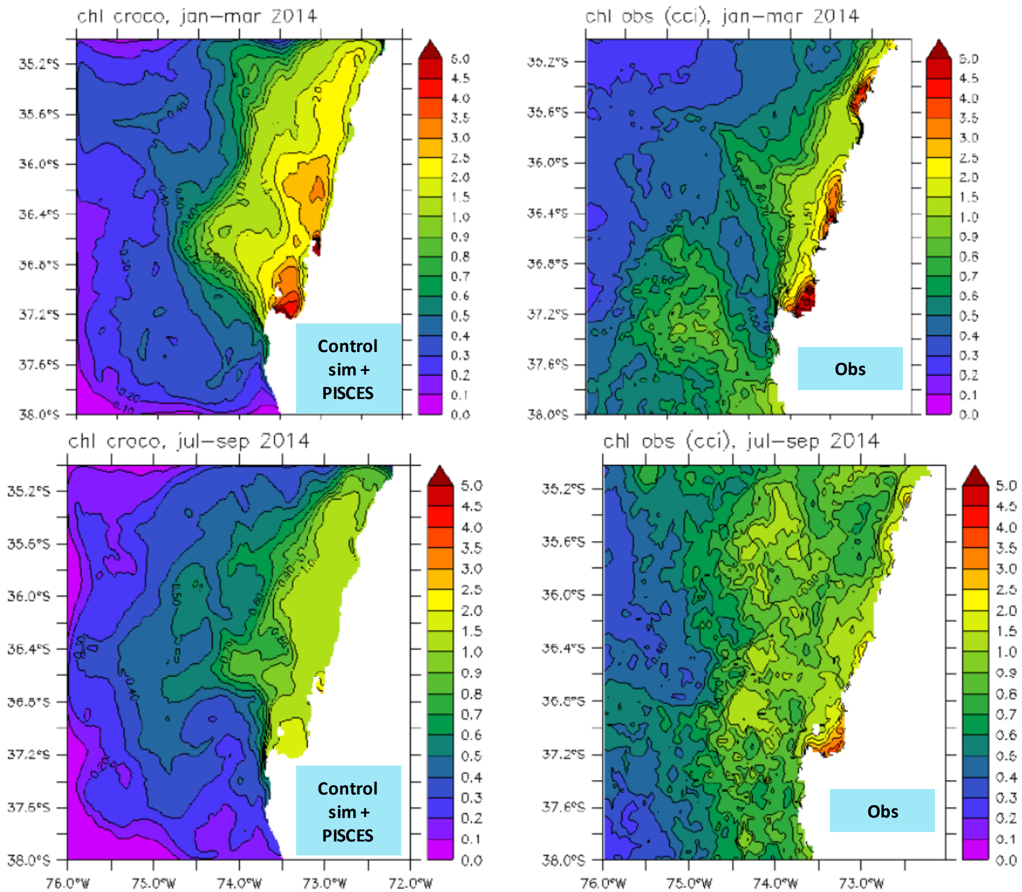
# Work in progress..........




**“ No river simulation” + PISCES**

**Interannual simulation:** from 1 january 2013 to 31 december 2018, daily outputs.

**Whitout rivers**

**“Control simulation” + PISCES”**

**Interannual simulation:** from 1 january 2013 to 31 december 2018, daily outputs.

**Interannual rivers discharge (2013-2018):** Biobío, Itata, Maule y Mataquito (Dirección General de Aguas, http://www.dga.cl)).

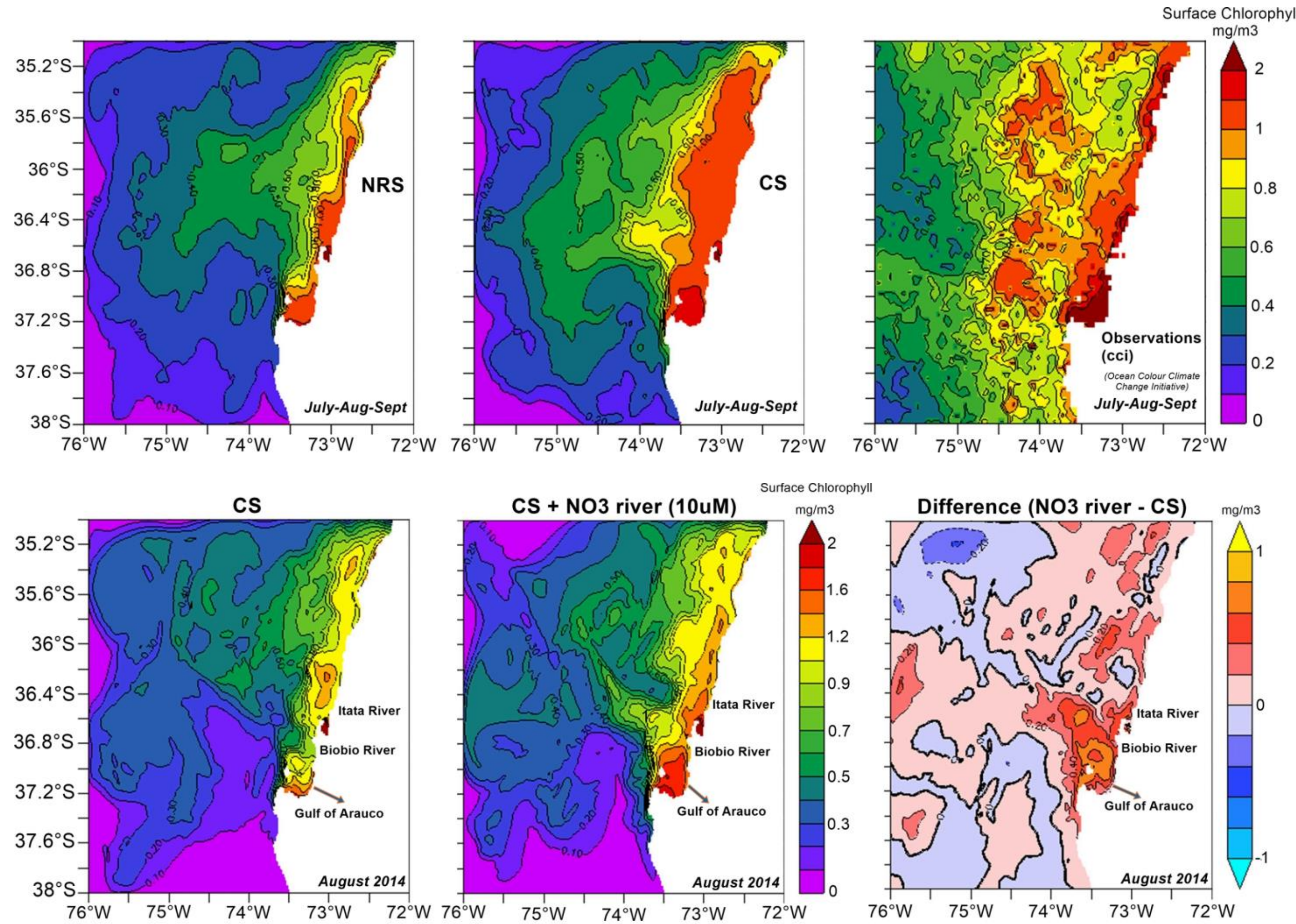
**“Control simulation” + PISCES + nutrients by rivers**

**Interannual simulation:** from 1 january 2013 to 31 december 2018, daily outputs.

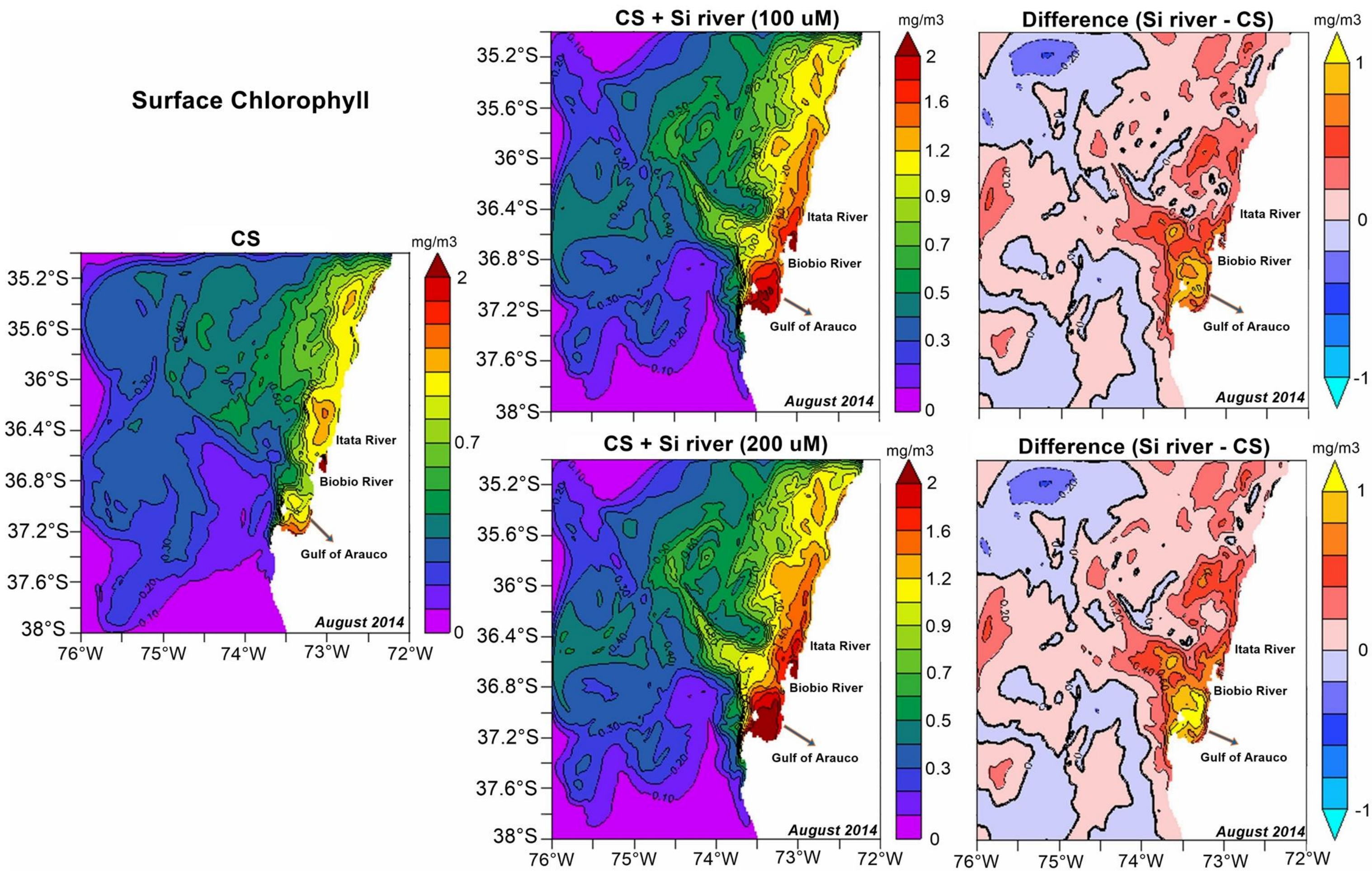
**Interannual rivers discharge (2013-2018):** Biobío, Itata, Maule y Mataquito.

**Rivers biogeochemical variables**: Si, NO3, Fe, PO4, NH4 (EULA+DGA)

# Work in progress……….

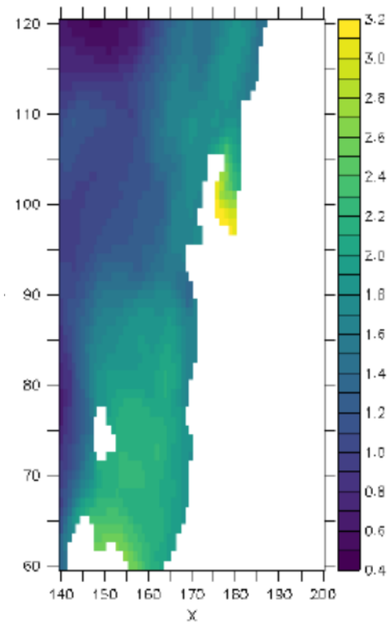


# Work in progress……….



Work in progress……….

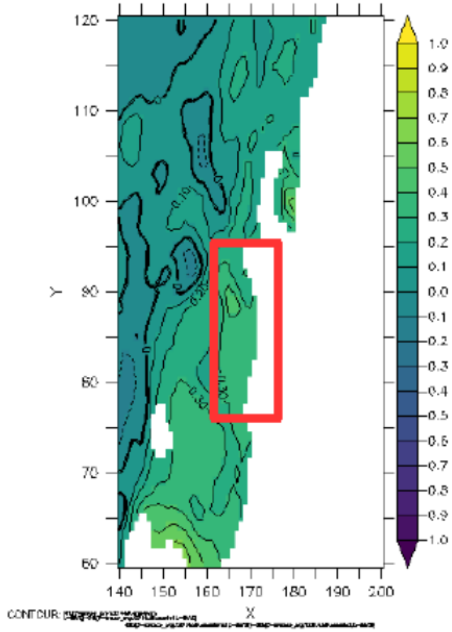
## Surface Chla




NCHL+DCHL

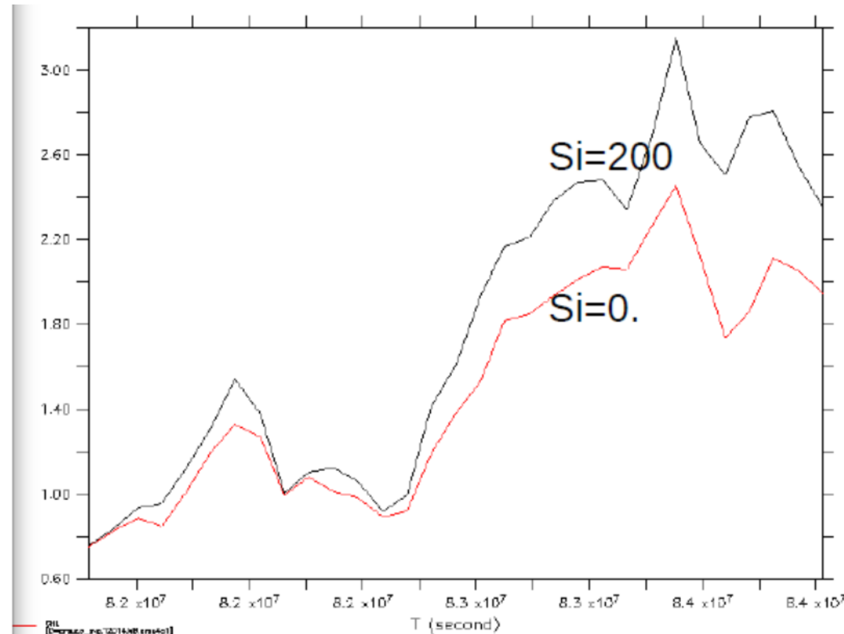
**“Control simulation” + PISCES**

## Difference




**“Control simulation” + PISCES + nutrients by rivers (Si)**

DATA SET: arauco_avg.Y2014.M8.arau4rvn1




NCHL+DCHL

Si= 0, Control sim + PISCES
Si=200 uM, River-BGQ sim