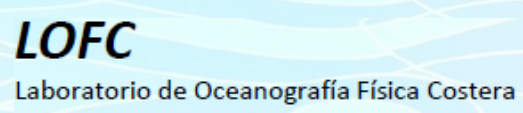
Summer School
CROCO Advanced Course
Biogeochemical application
17-18 January 2022

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

Odette A. Vergara Soto



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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

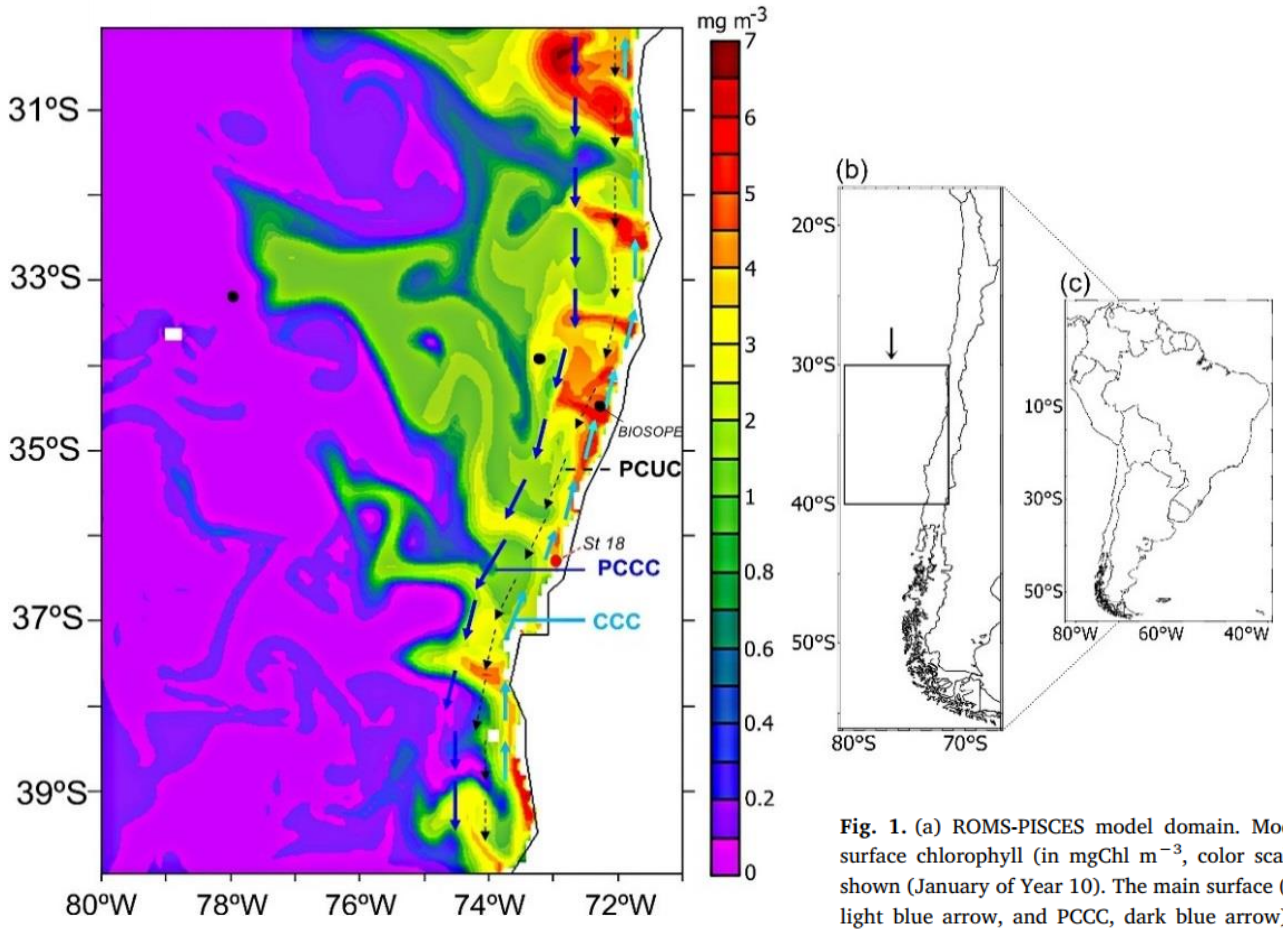


Fig. 1. (a) ROMS-PISCES model domain. Modeled surface chlorophyll (in mgChl m^{-3}, color scale) is shown (January of Year 10). The main surface (CCC, light blue arrow, and PCCC, dark blue arrow) and subsurface (PCUC, black dashed arrow) nearshore currents of the HCS are indicated. Station 18 is marked 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:

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

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

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

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

Nutrient limitation:

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

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

Physical mechanisms of nutrient transport

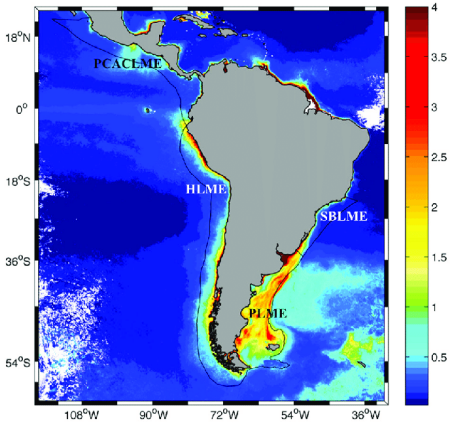
$$\frac{dC}{dt} = -\mu\partial xC - v\partial yC - \omega\partial zC + (\partial z(\kappa\partial zC))$$

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

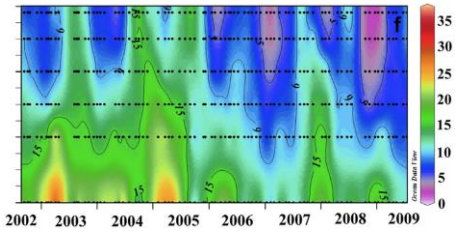


SeaWIFS
(Sea-Viewing Wide Field-of-View Sensor
-2000-2006

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

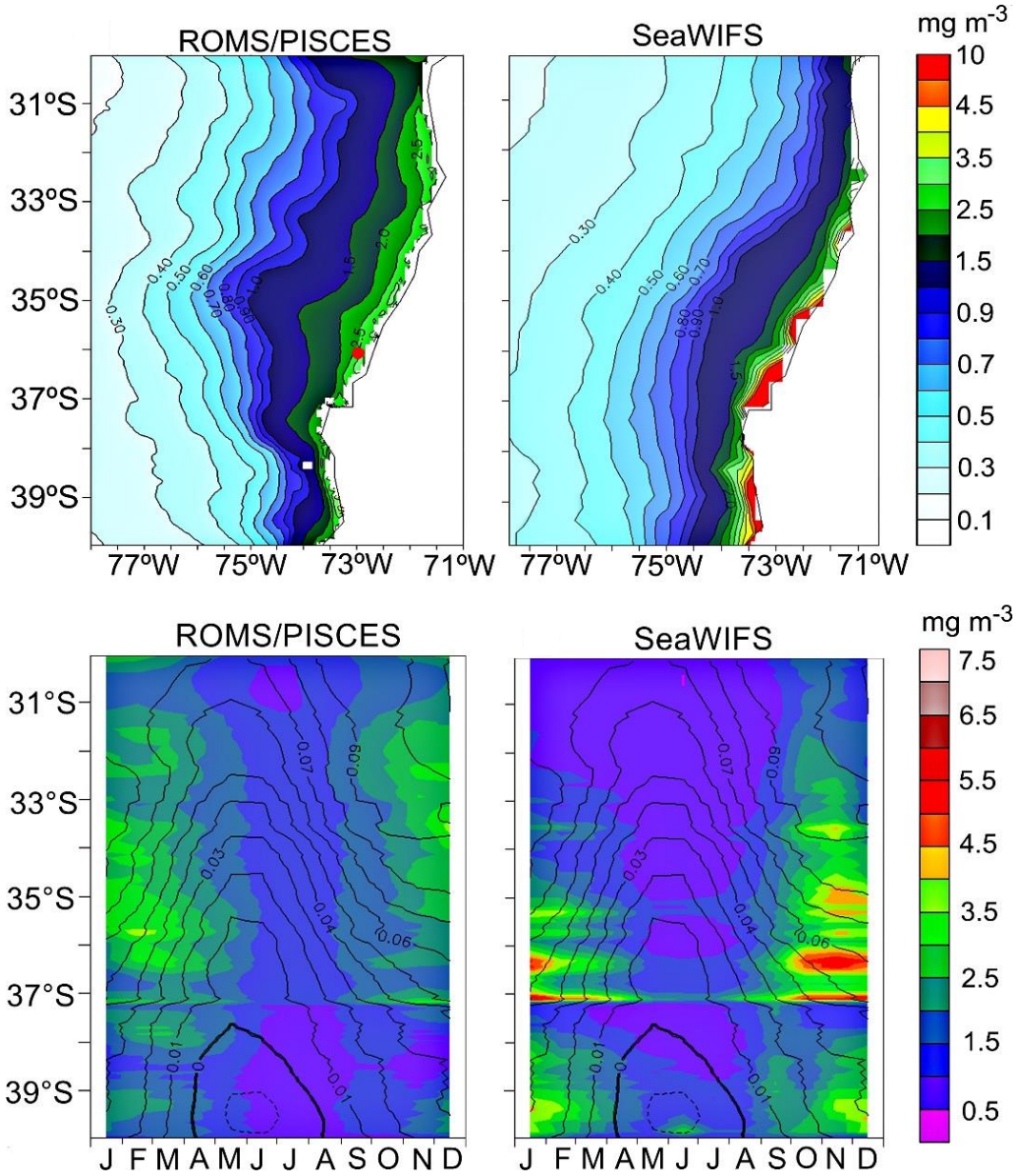


Fig. 3. Annual mean surface chlorophyll (in mg Chl-a m^{-3}) estimated by (a) the model (red circle: Station 18) and (b) SeaWIFS observations (1998–2006). Annual cycle of surface chlorophyll within a 100 km coastal band in (d) the model, and (e) SeaWIFS. Annual along-shore wind stress (in N m^{-2}) cycle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

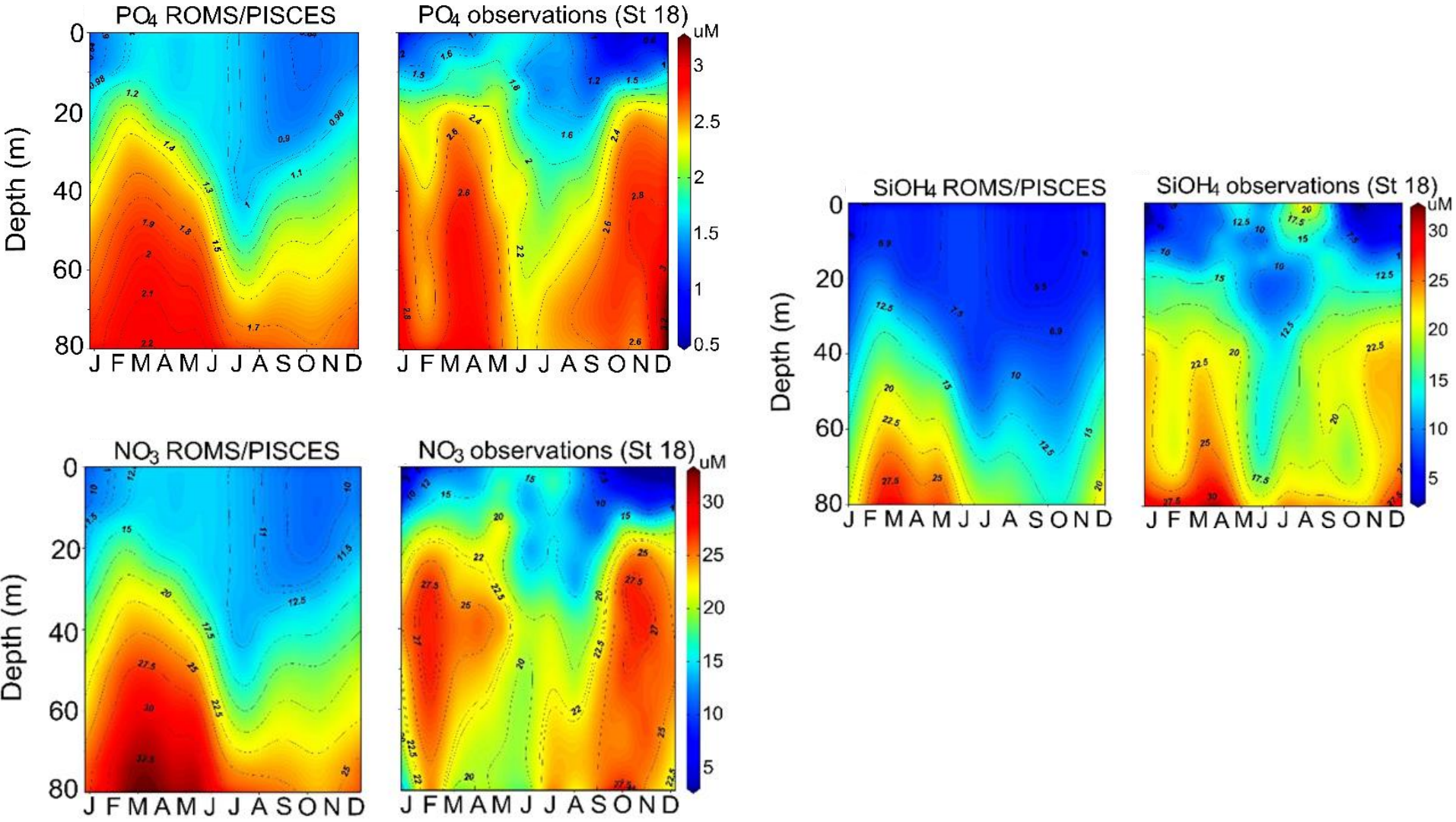
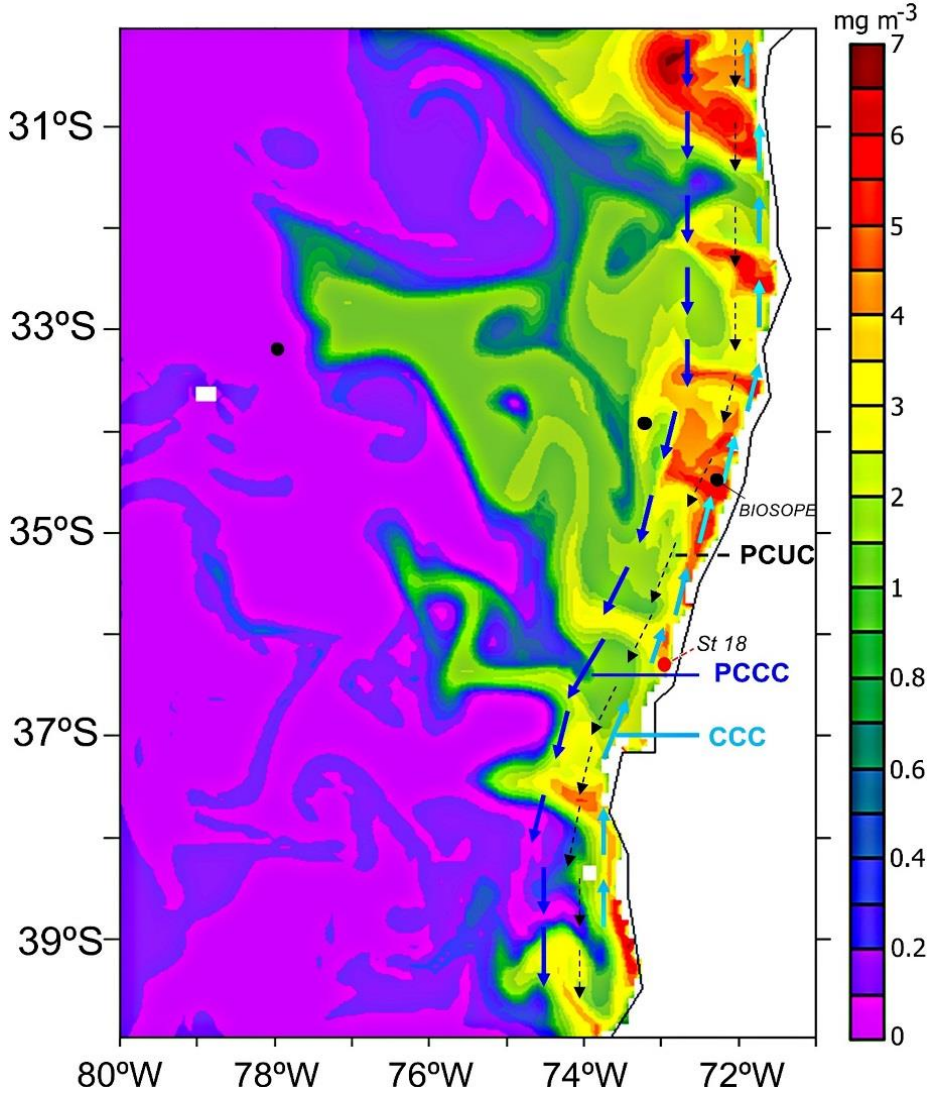


Fig. 5. Seasonal cycle of (a) Modeled phosphate, (c) nitrate and (e) silicate versus observed values (b, d, f) at Station 18. Units are $\mu mol\, l^{-1}$.

General assessments of simualtion



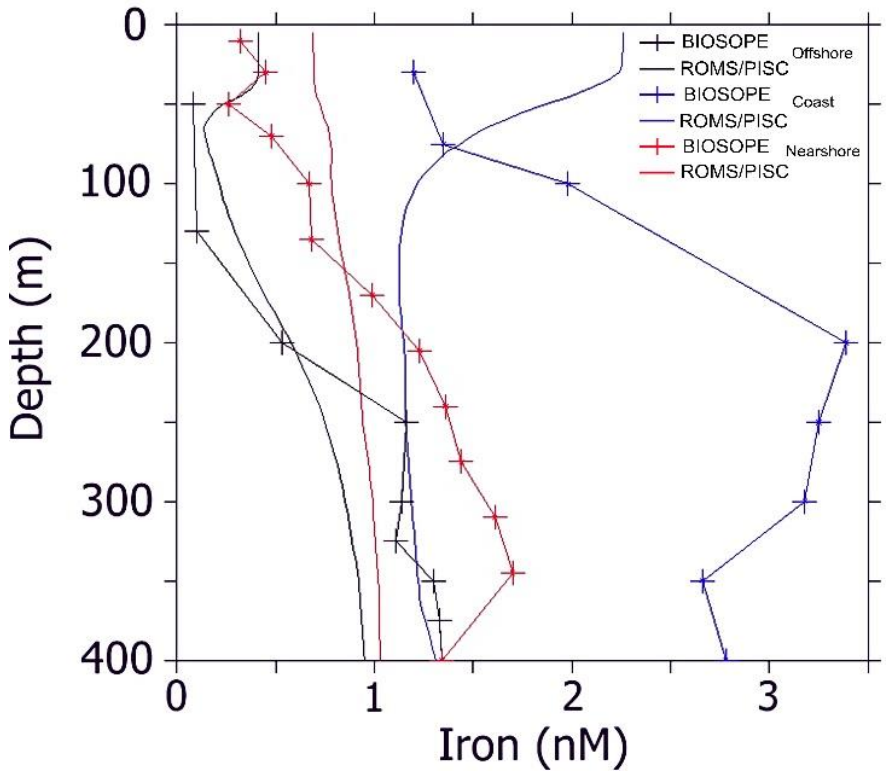


Fig. 6. Iron profiles from model simulations (lines) and BIOSOPE (lines with crosses) measurements (Blain et al., 2008; Bonnet et al., 2008) at three stations (see location in Fig. 1): "offshore" (33.36°S, 78°W; black), "nearshore" (33.8°, 73.5°W; red) and "coastal" (34.5°S; 72.4°W; blue) profiles.

Surface co-limitation

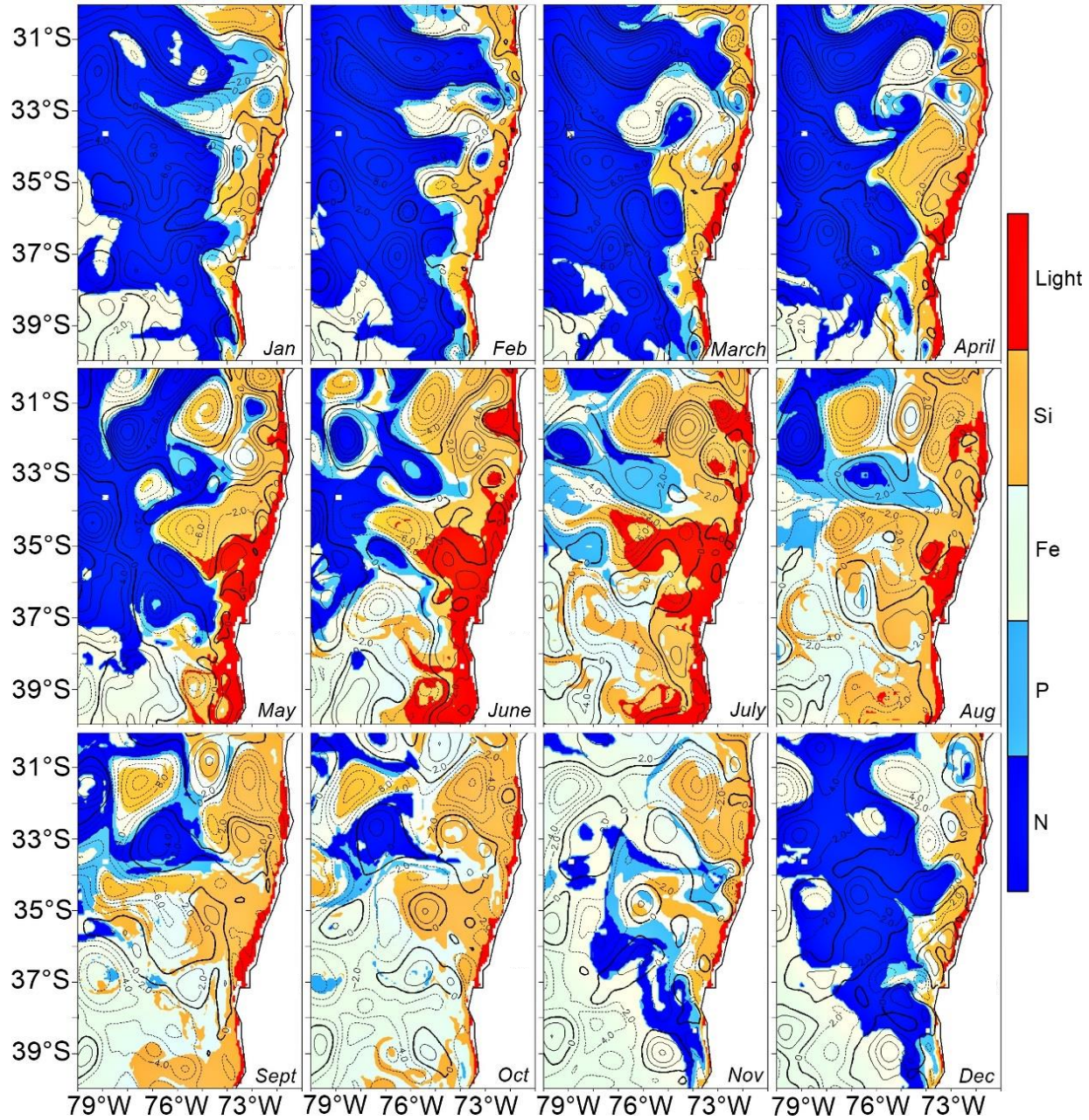


Fig. 7. Maps of surface co-limitation fields during Year 10, from January to December between 0–20 m. Colors indicate whether nutrients or light are limiting. Contours (in cm) represent the sea level anomaly.

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)

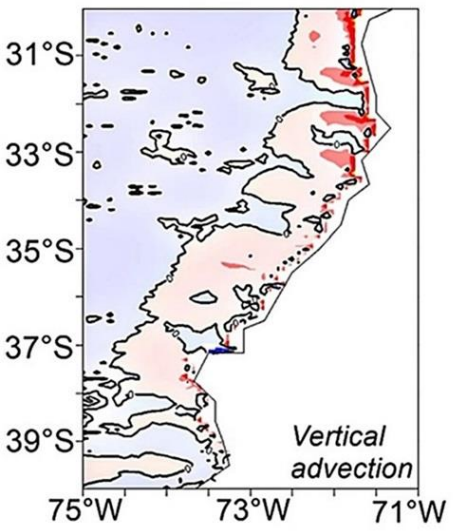
Fe

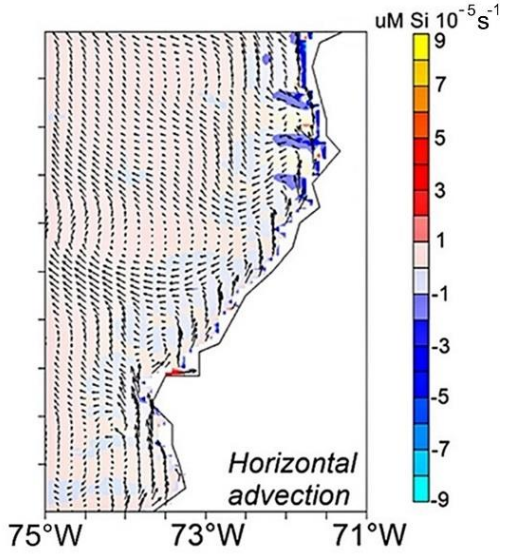
Spring
Offshore (100-600 km)

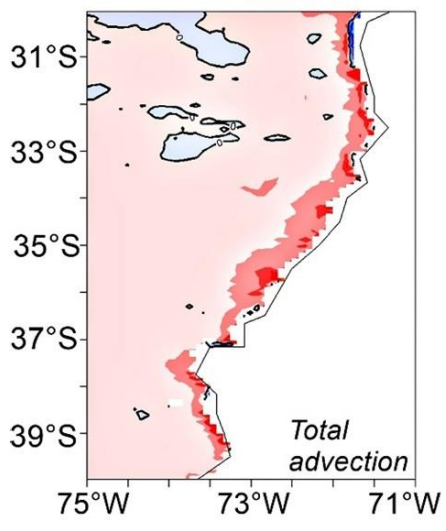
Phosphate

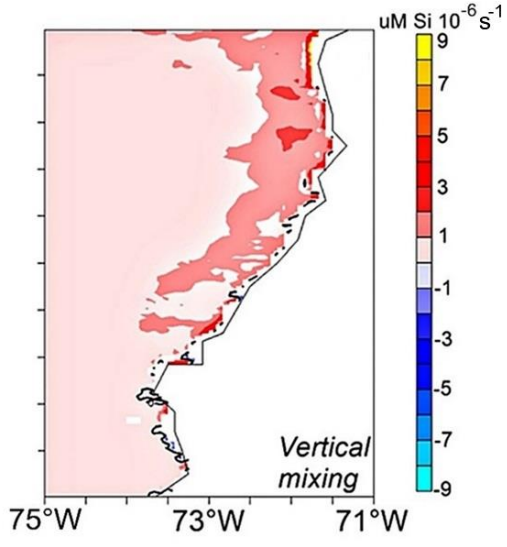
Winter
Offshore
(100-300 km, 30°-34°S)

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

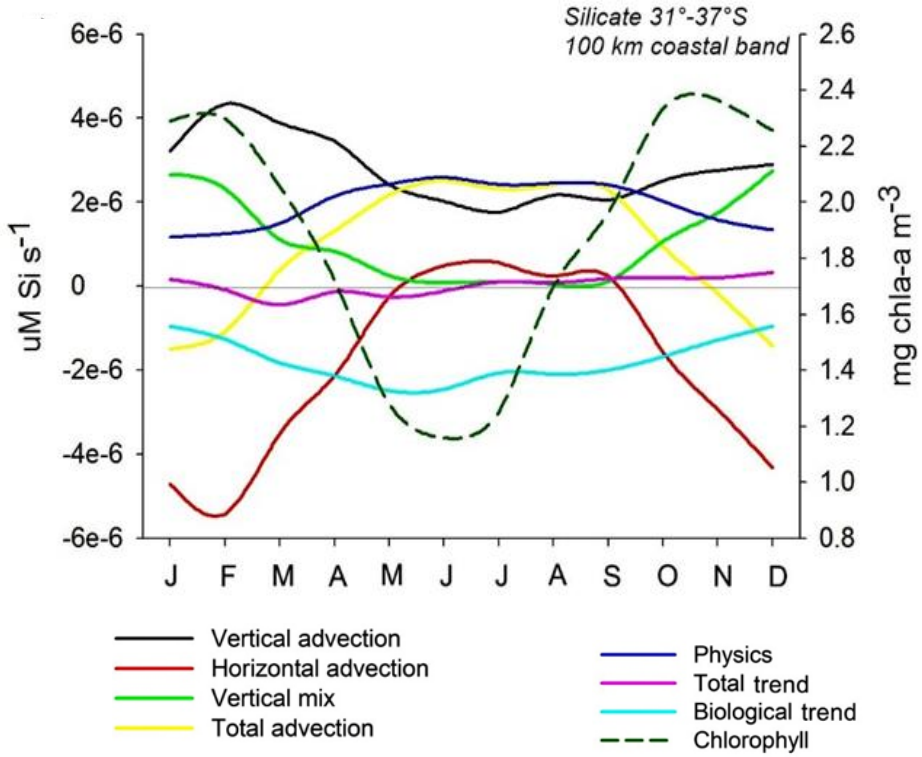
The input of nutrients through vertical mixing was positive everywhere, mainly between 30°S and 36°S.

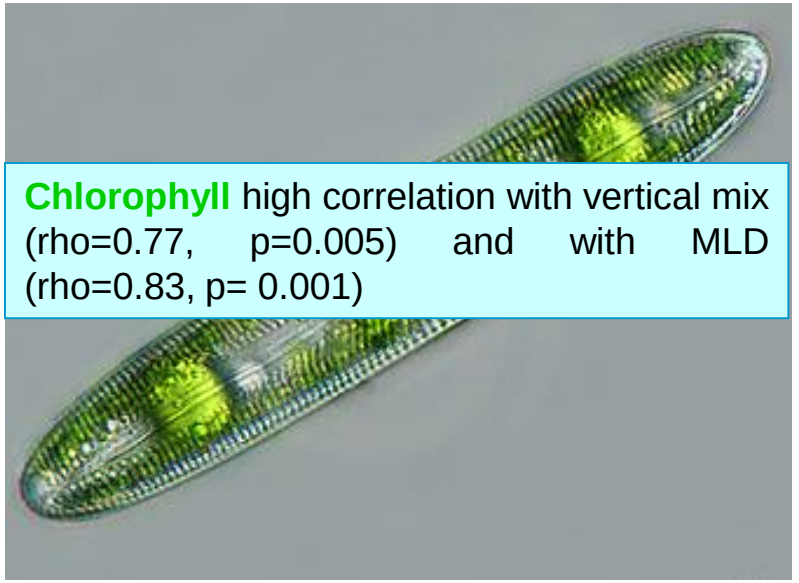
balanced

Vertical advection ⟷ Horizontal advection

compensated

Vertical mix





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

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.

MOSA-ROMS (South-Austral Operational Model)

www.ifop.cl/chonos

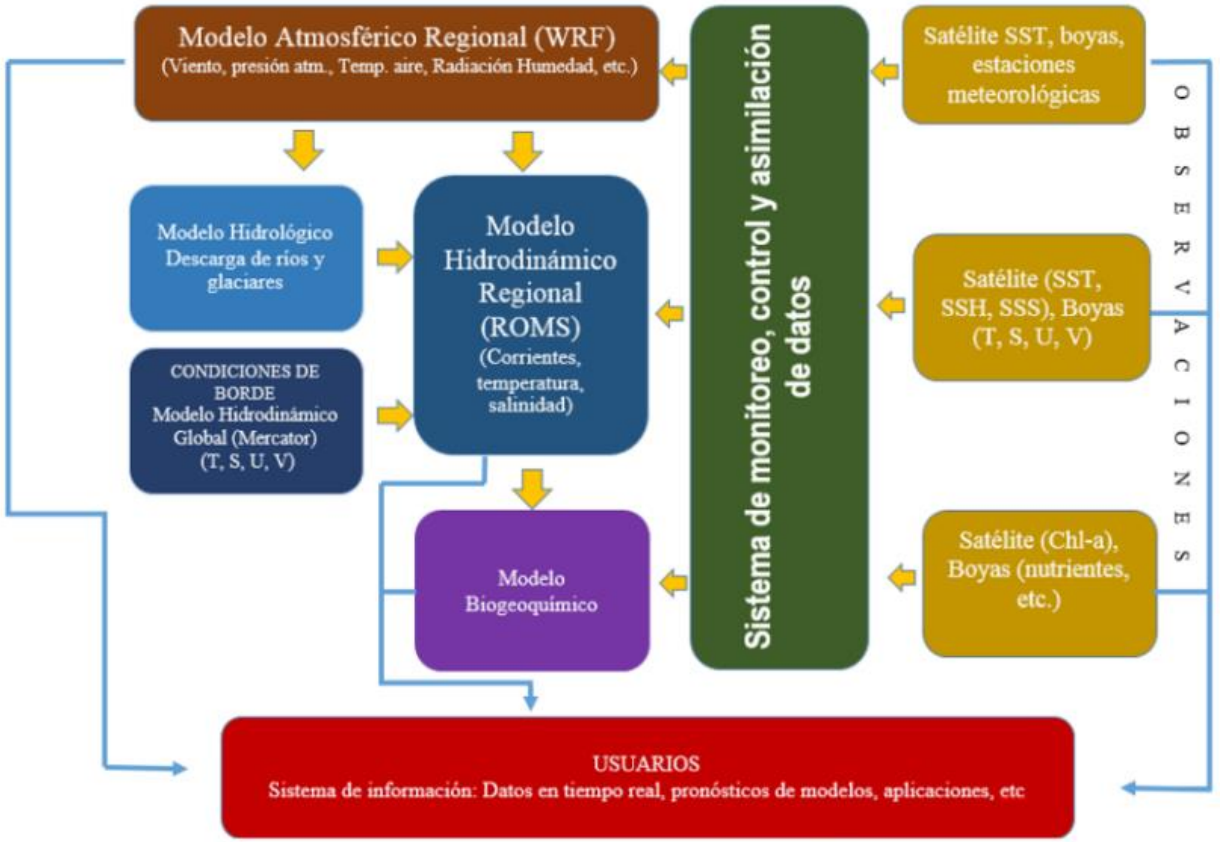


Figura 1: *Modelo conceptual propuesto para el desarrollo a largo plazo del modelo operacional Sur-Austral, MOSA, el cual incluye todos los elementos contemplados en etapas futuras de desarrollo.*

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

SUBSECRETARÍA DE ECONOMÍA Y EMT / Octubre 2020

MOSA-ROMS

Horizontal resolution = 1km

Boundary conditions = Mercator-Ocean

Initial condition = From the forecast generated the previous day.

Atmospheric forcing = 5 km MOSA-WRF.

Fresh water forcing = Point sources, flows from hydrological models and DGA.

Bathymetry = SHOA + GEBCO

Vertical levels = 42 sigma levels.

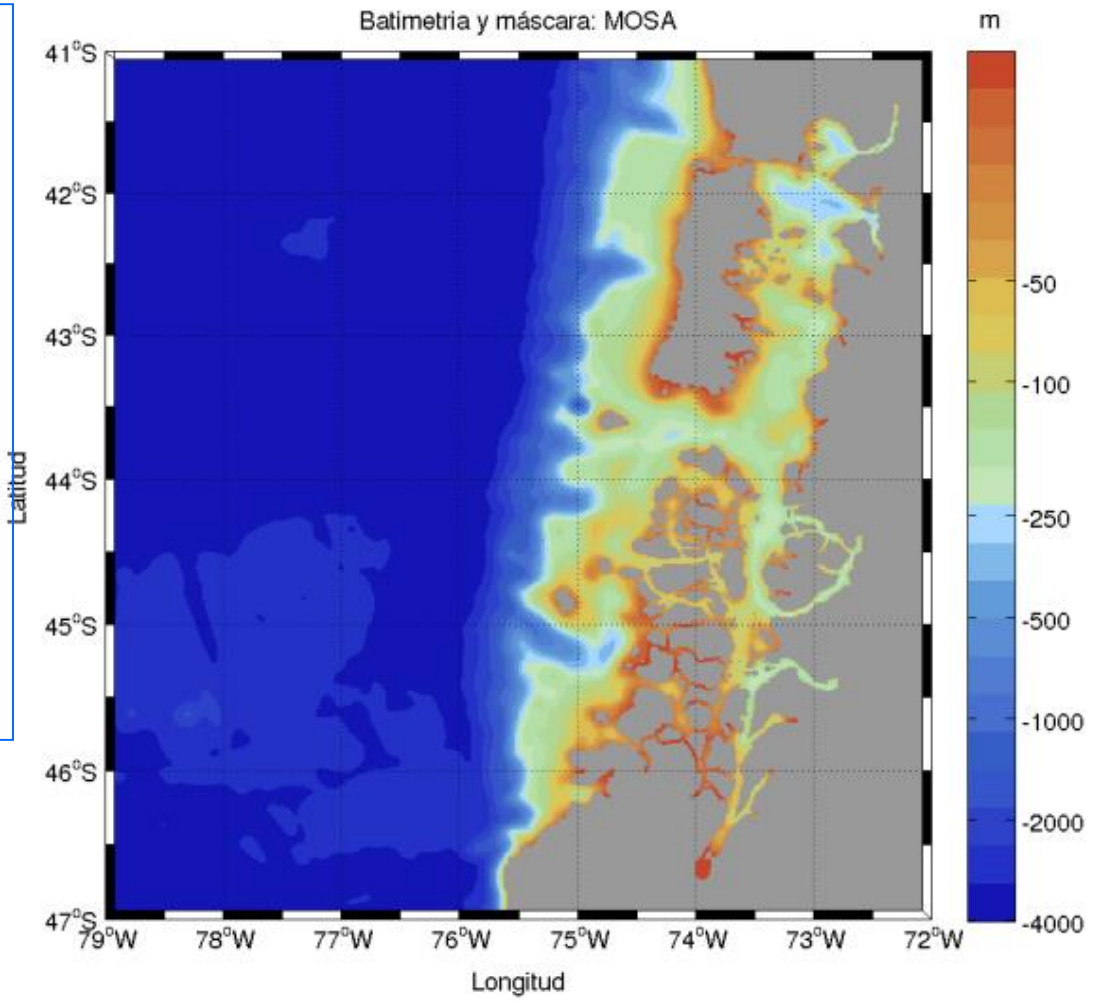


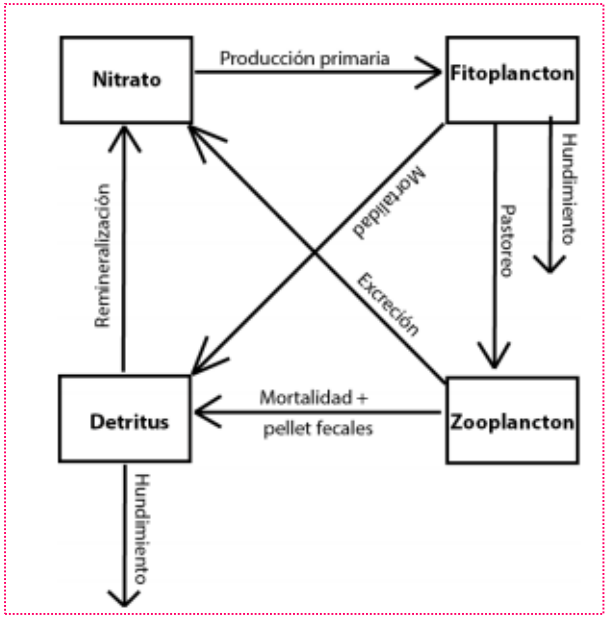
Figura 3: *Batimetría del modelo operacional MOSA-ROMS interpolada desde datos GEBCO y cartas náuticas digitales del SHOA*

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

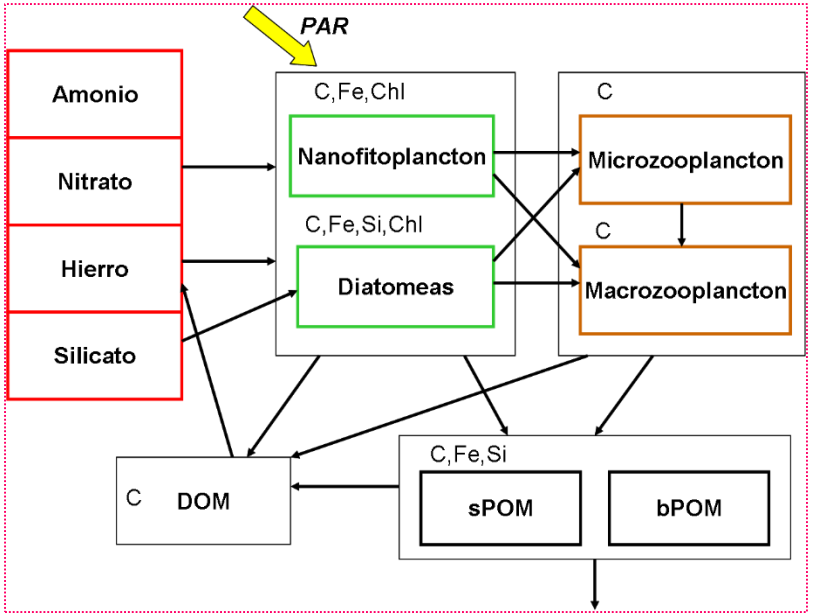
SUBSECRETARÍA DE ECONOMÍA Y EMT / Octubre 2020

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.

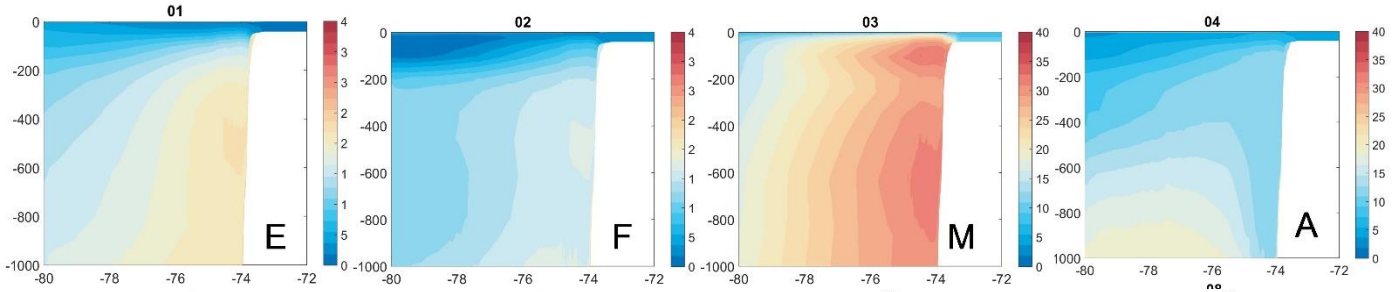
Los parámetros recopilados para las costas de Chile son los siguientes:

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).

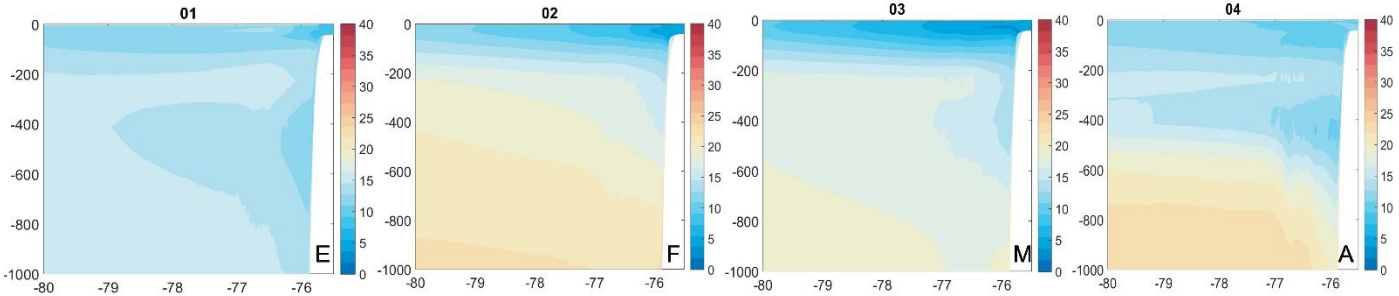
MOSA-PISCES: boundary conditions: WOA-PISCES

Nitrato (uM)

Norte →

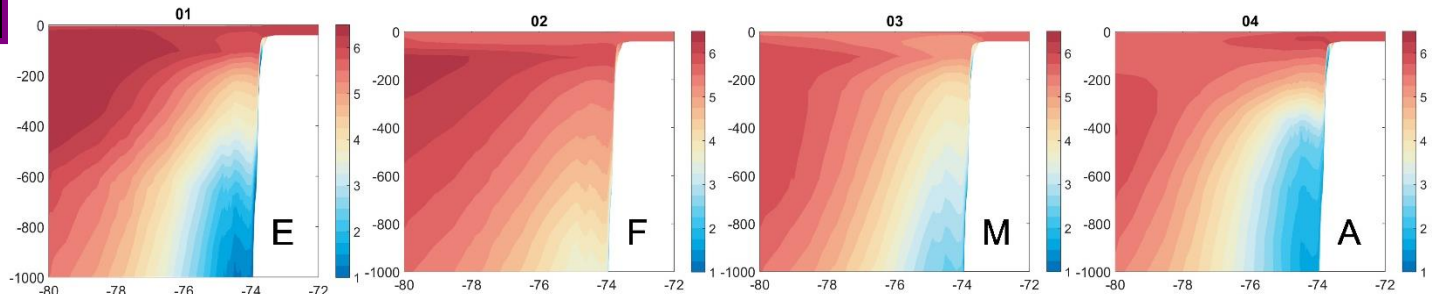


Sur →

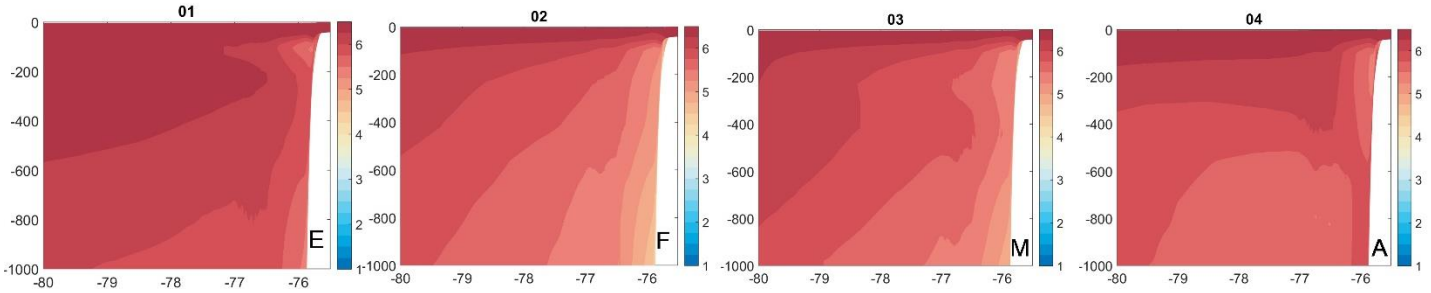


Oxígeno (ml/L)

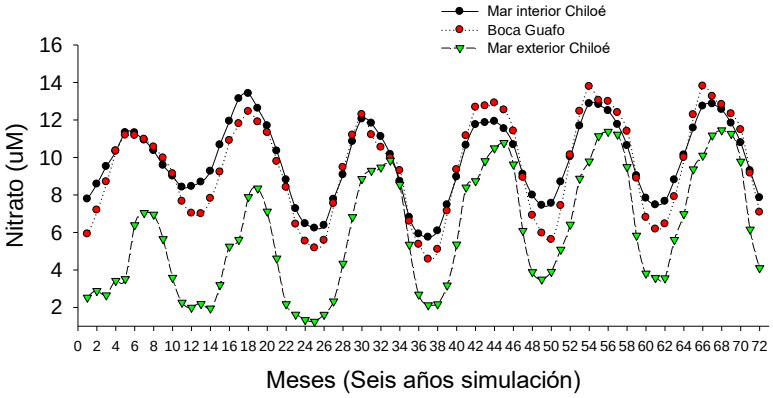
Norte →

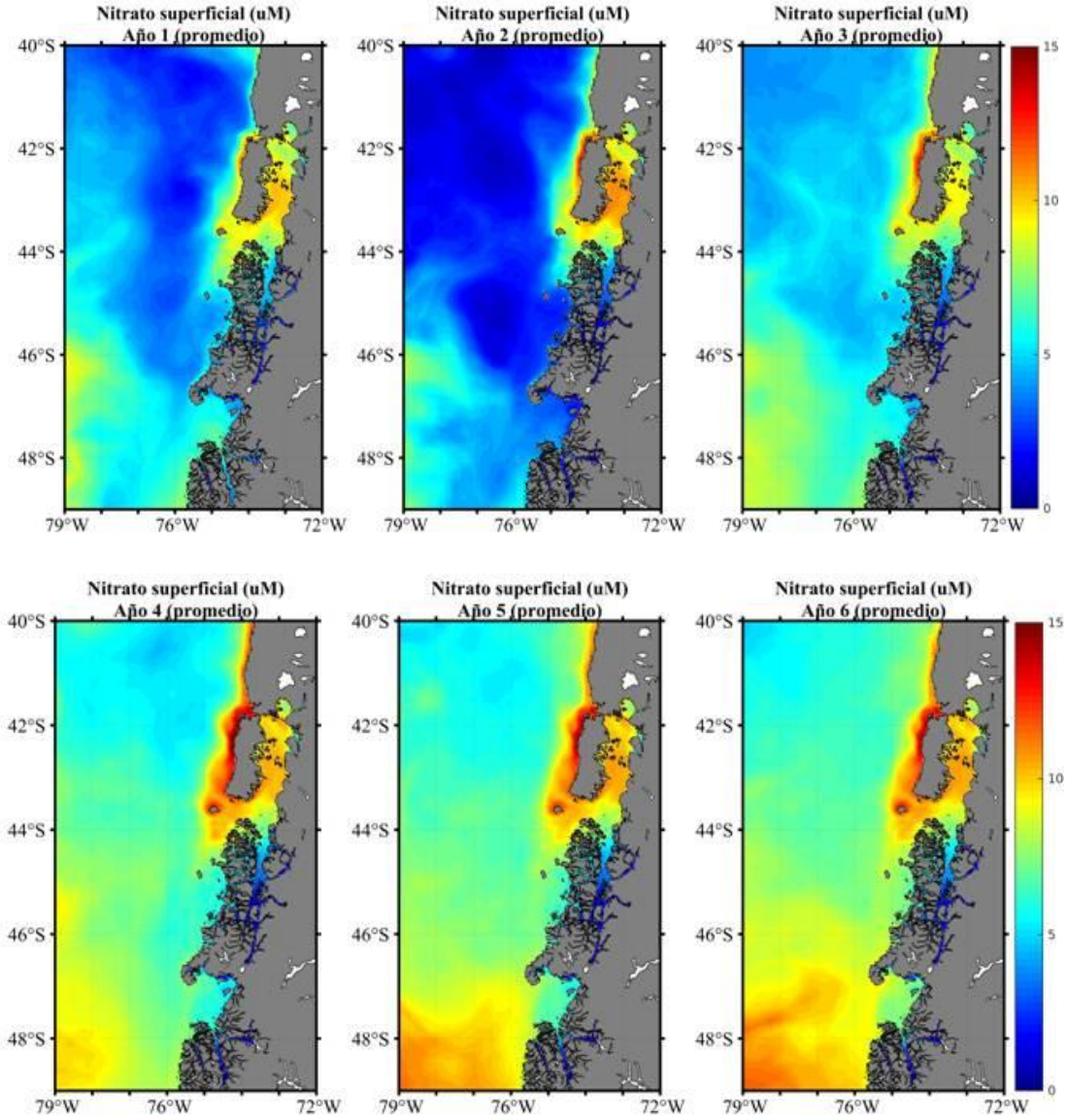


Sur →

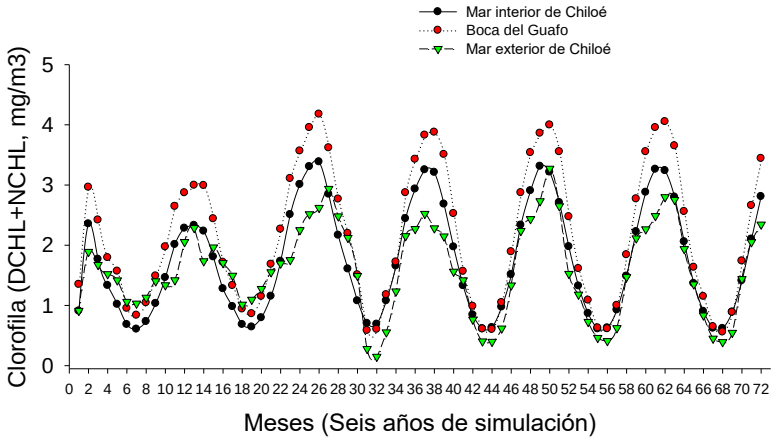


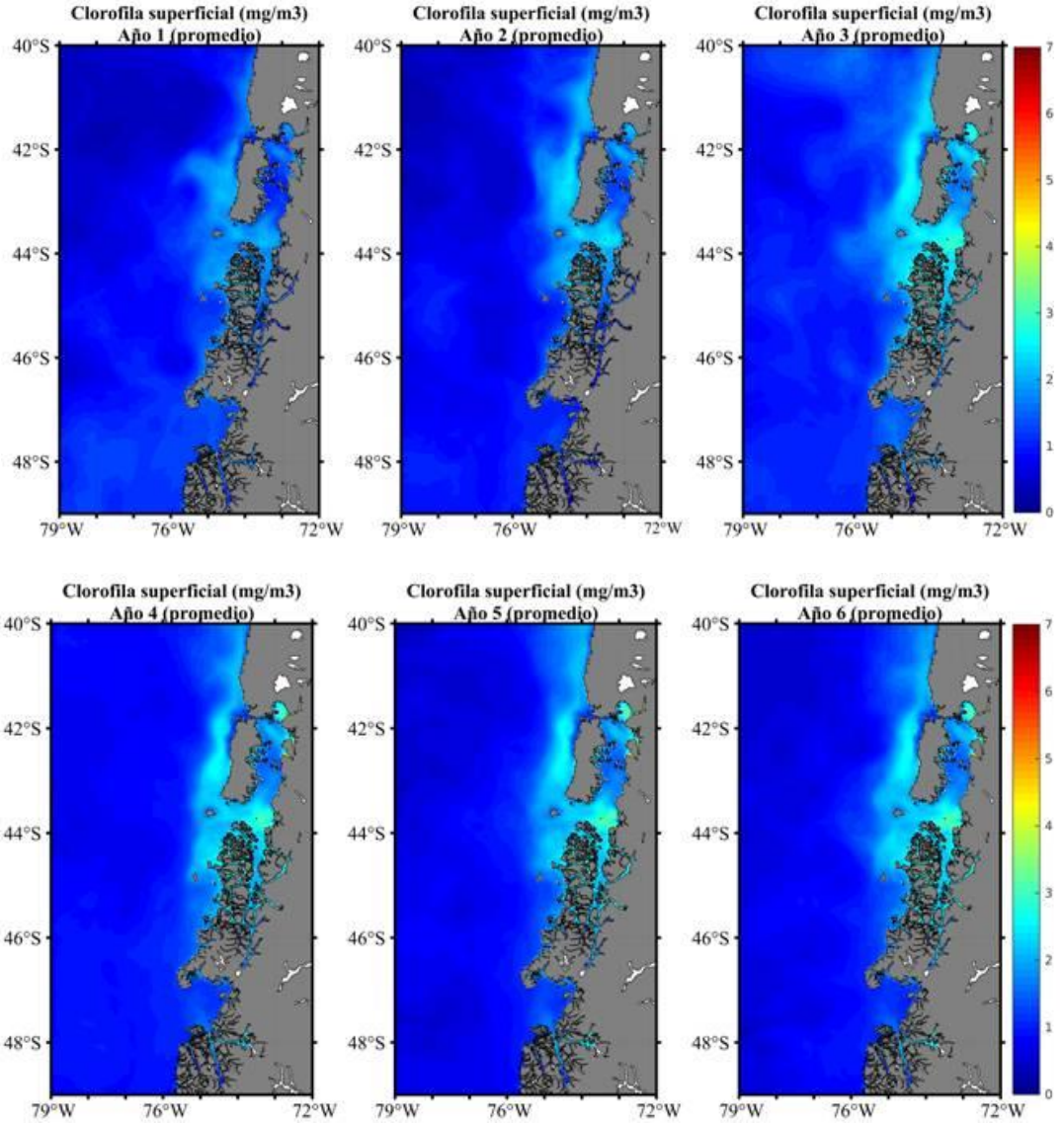
MOSA-PISCES: Results



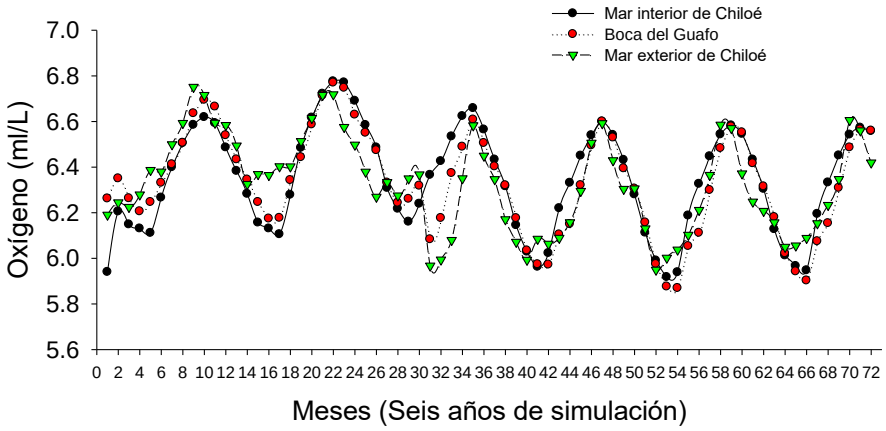


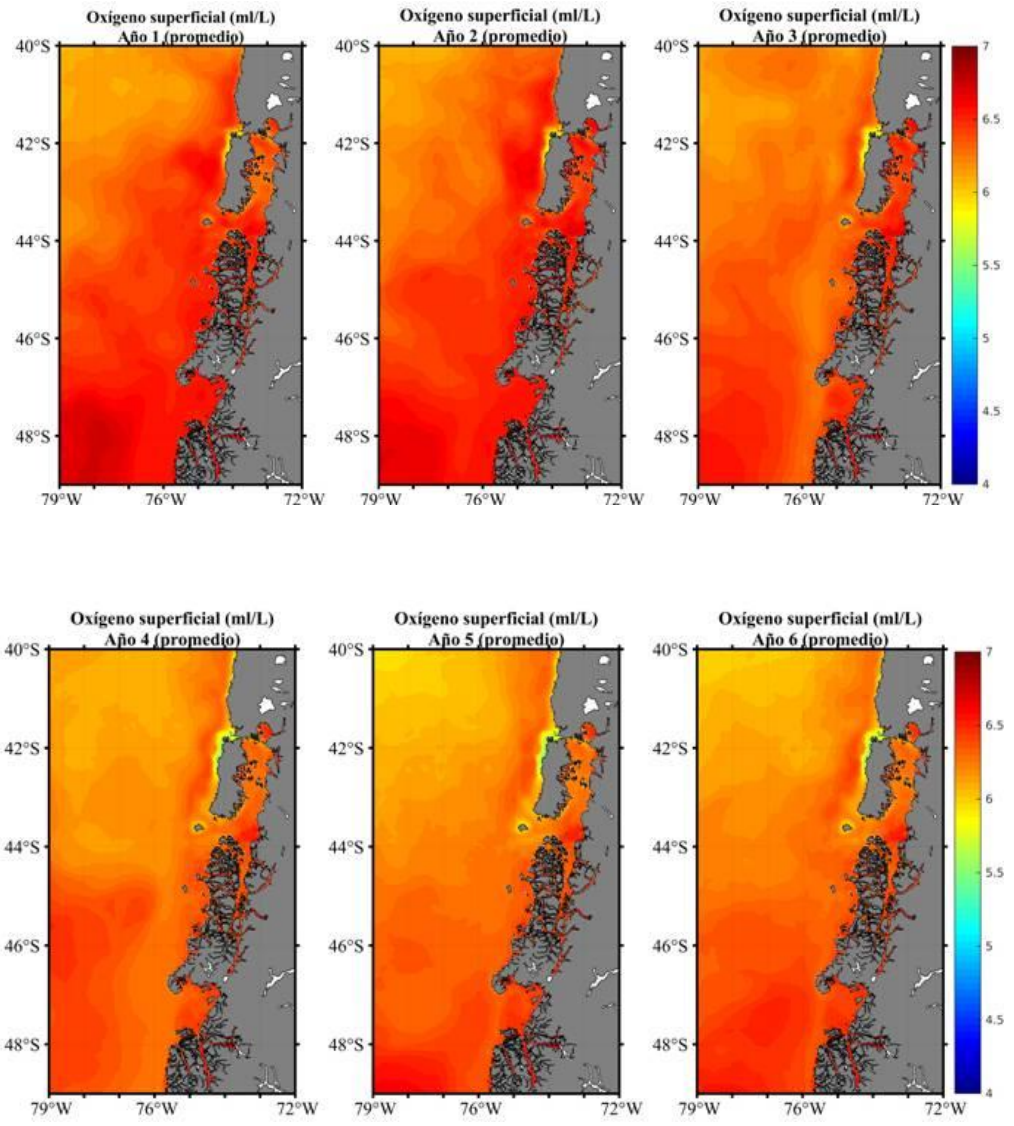
MOSA-PISCES: Results



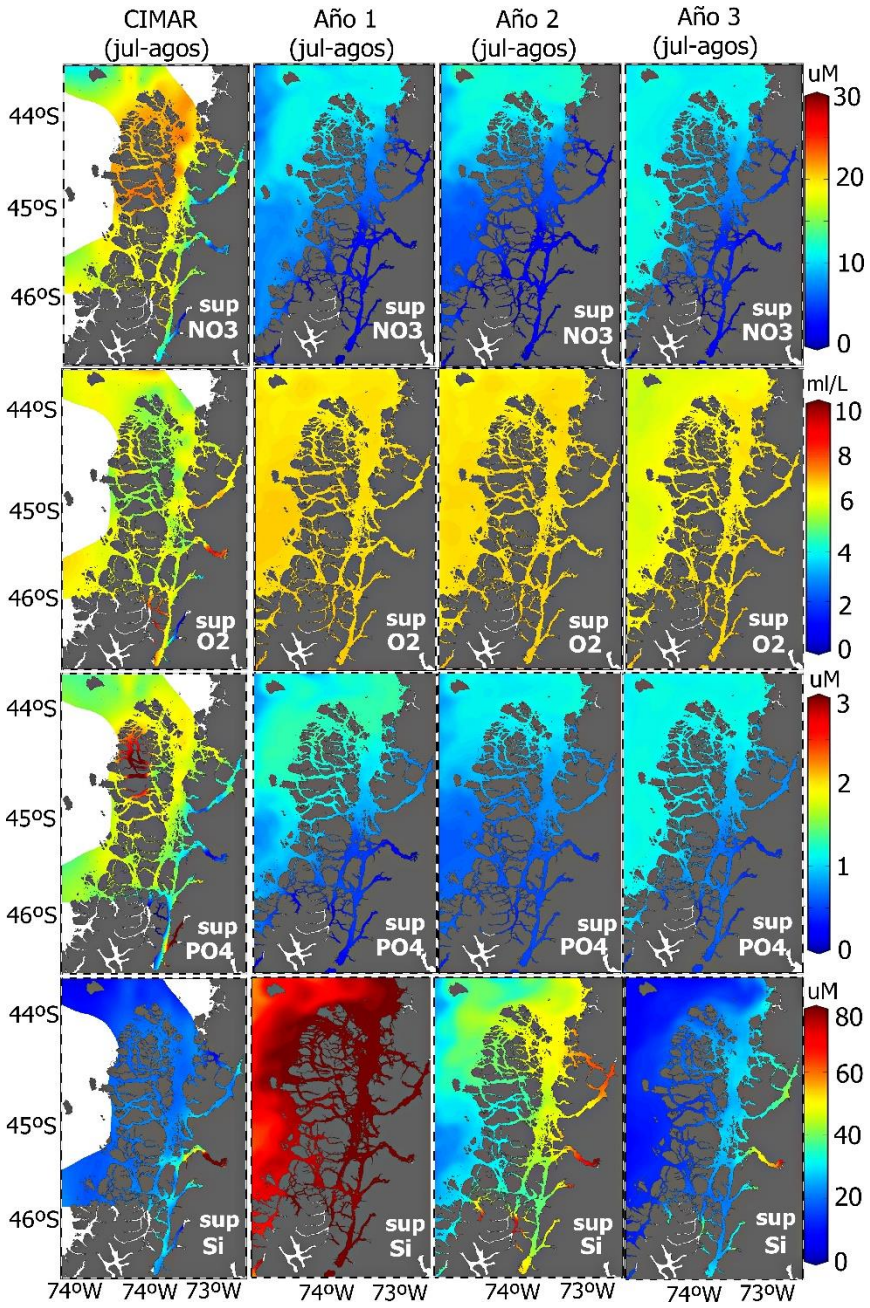


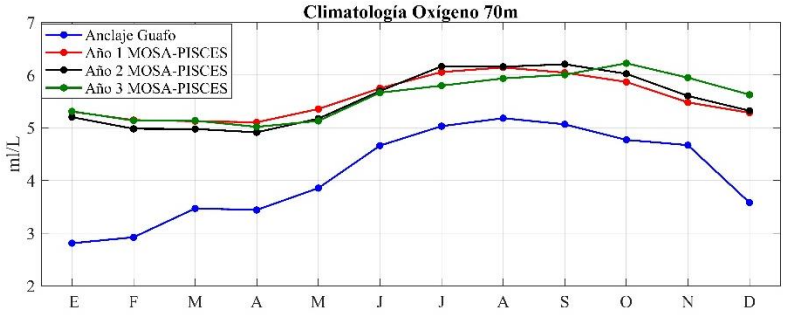
MOSA-PISCES: Results

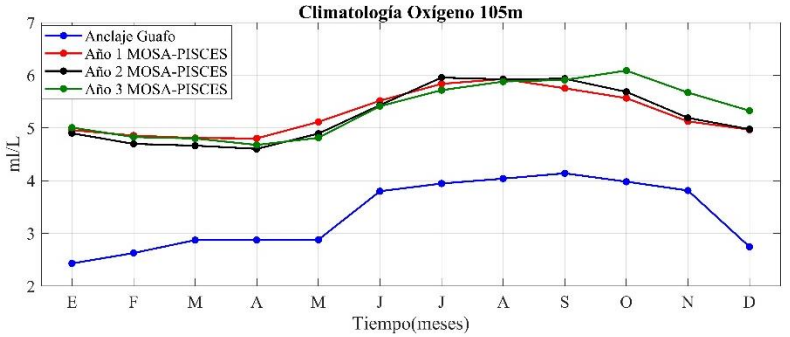


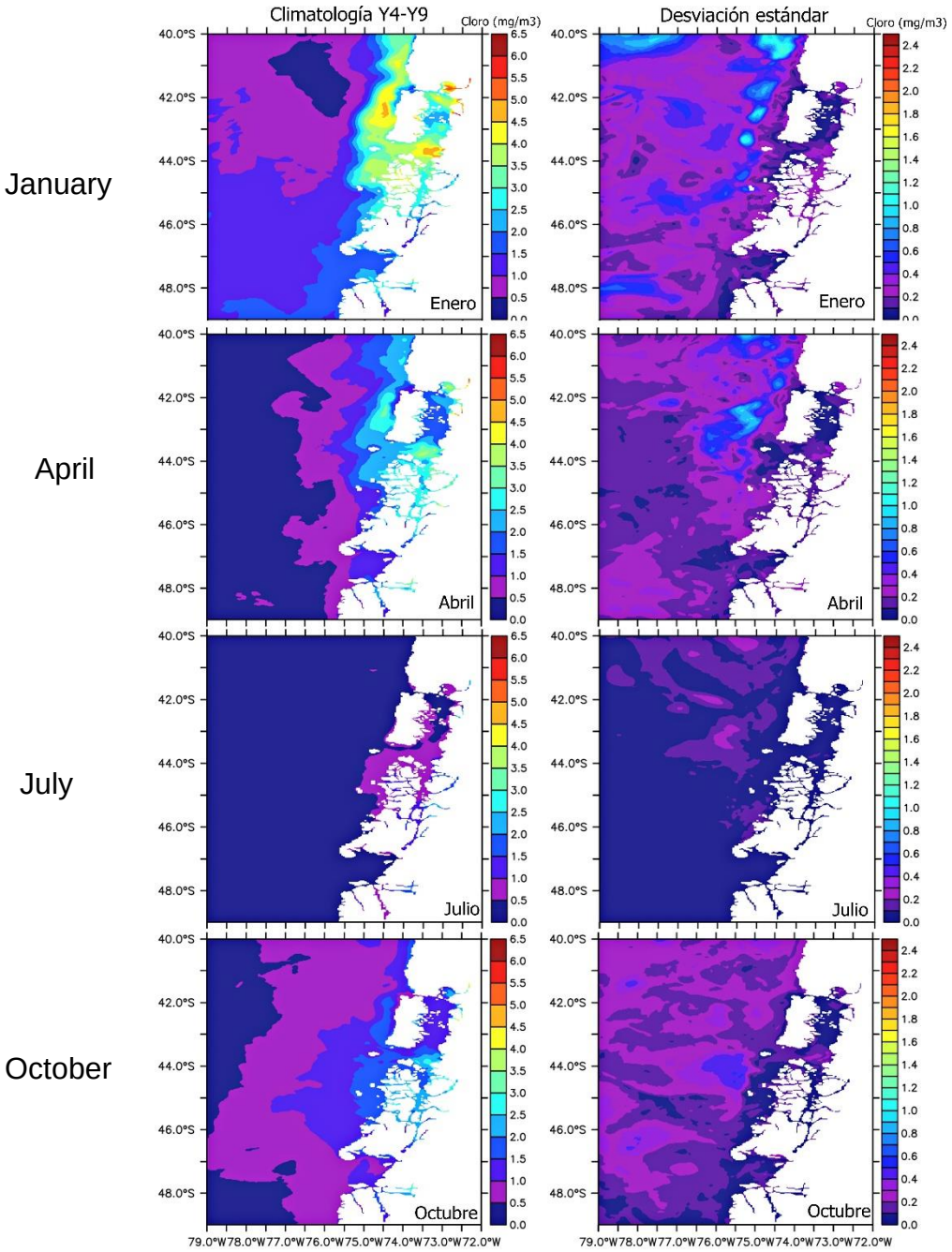


MOSA-PISCES - validation

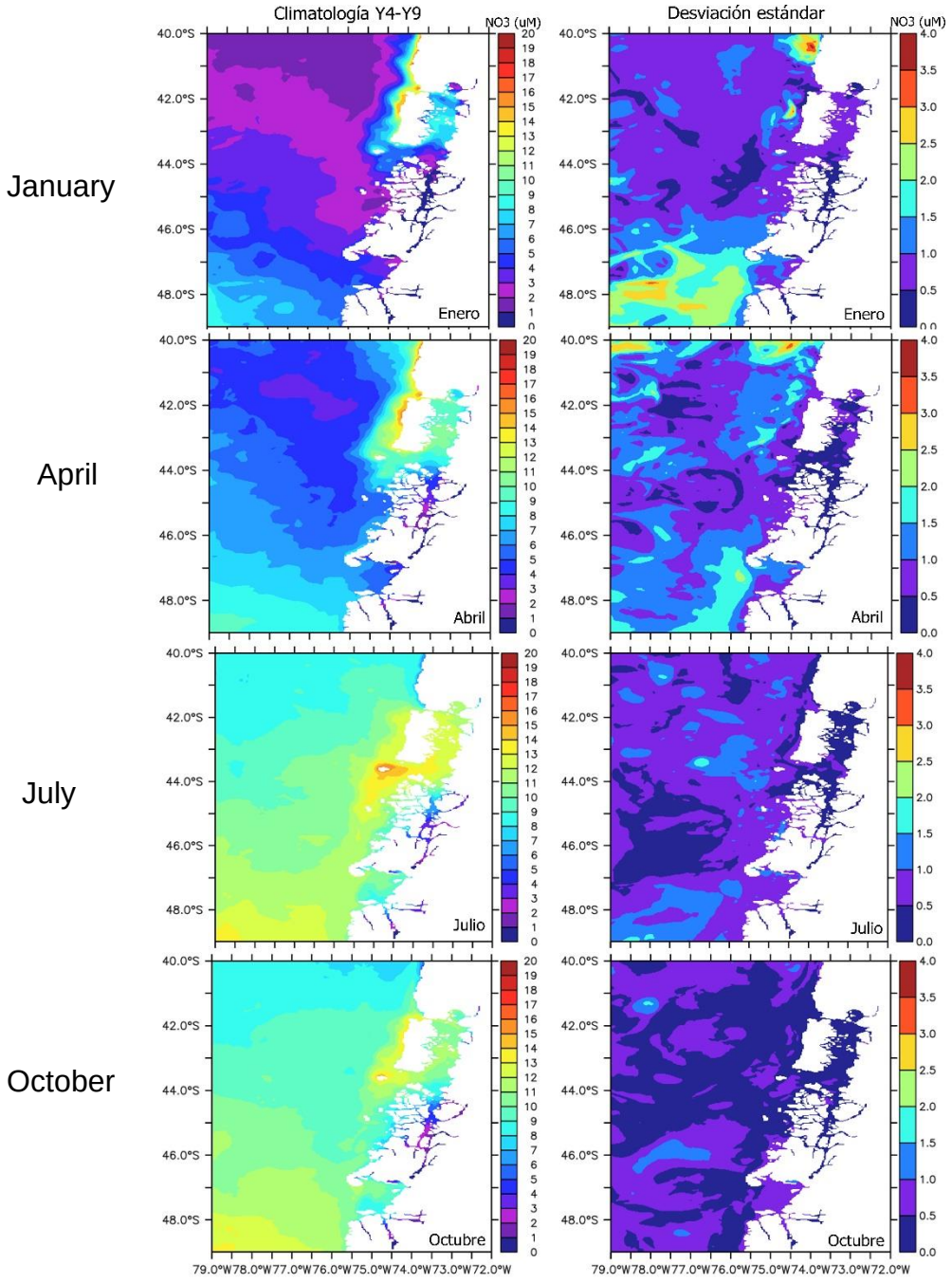







Climatología Y4-Y9
Desviación estándar
Cloro (mg/m3)
January
April
July
October
Enero
Abril
Julio
Octubre
40.0°S
42.0°S
44.0°S
46.0°S
48.0°S
79.0°W 78.0°W 77.0°W 76.0°W 75.0°W 74.0°W 73.0°W 72.0°W

MOSA-PISCES - Climatology



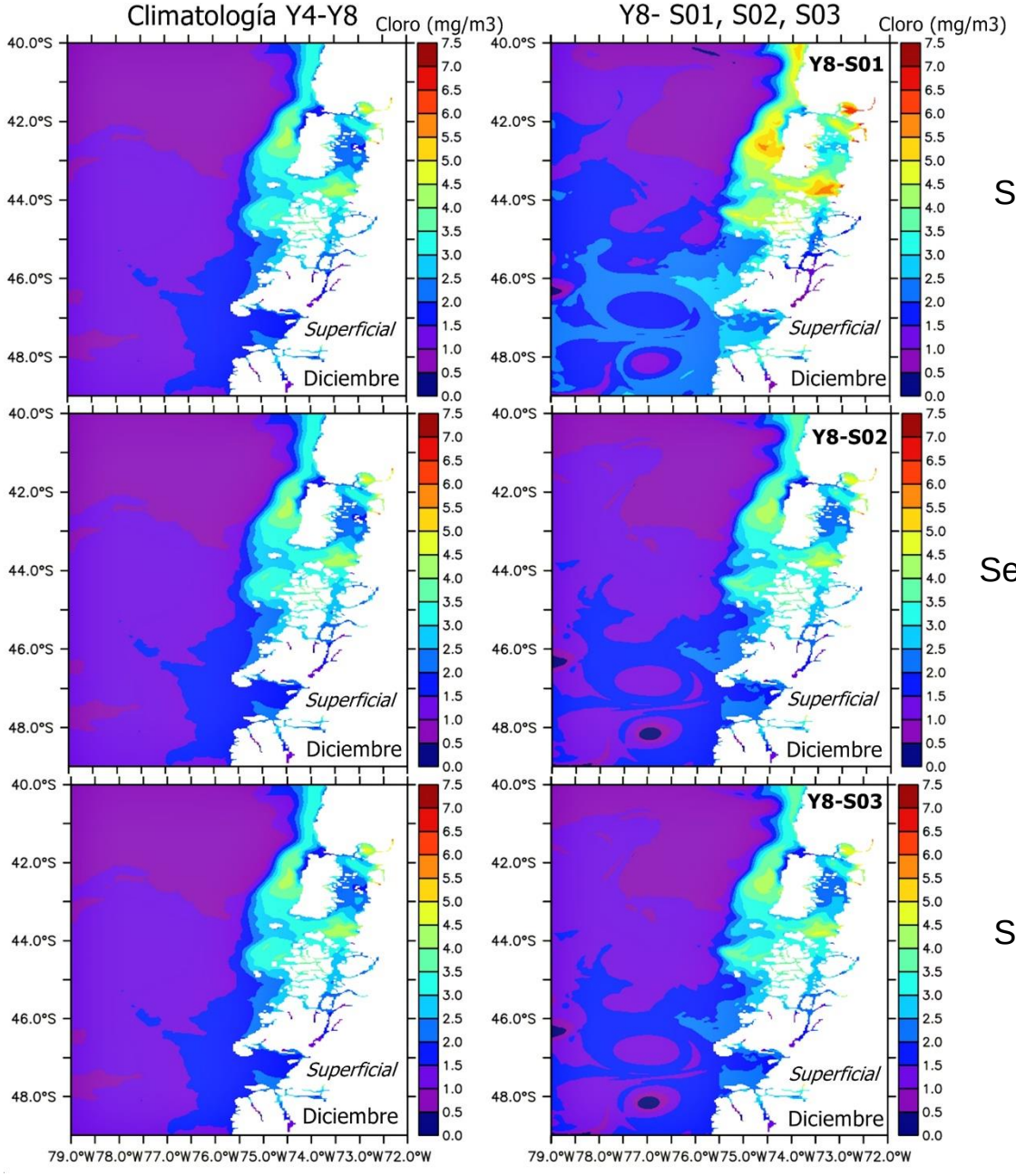
Experiment S01: Modification of parameters in the "namelist_pisces" to increase the concentration of chlorophyll and nitrate and decrease the concentration of oxygen.
The modified parameters are found in the nanophytoplankton, diatom, microzooplankton, mesozooplankton, nitrate, and oxygen equations, 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

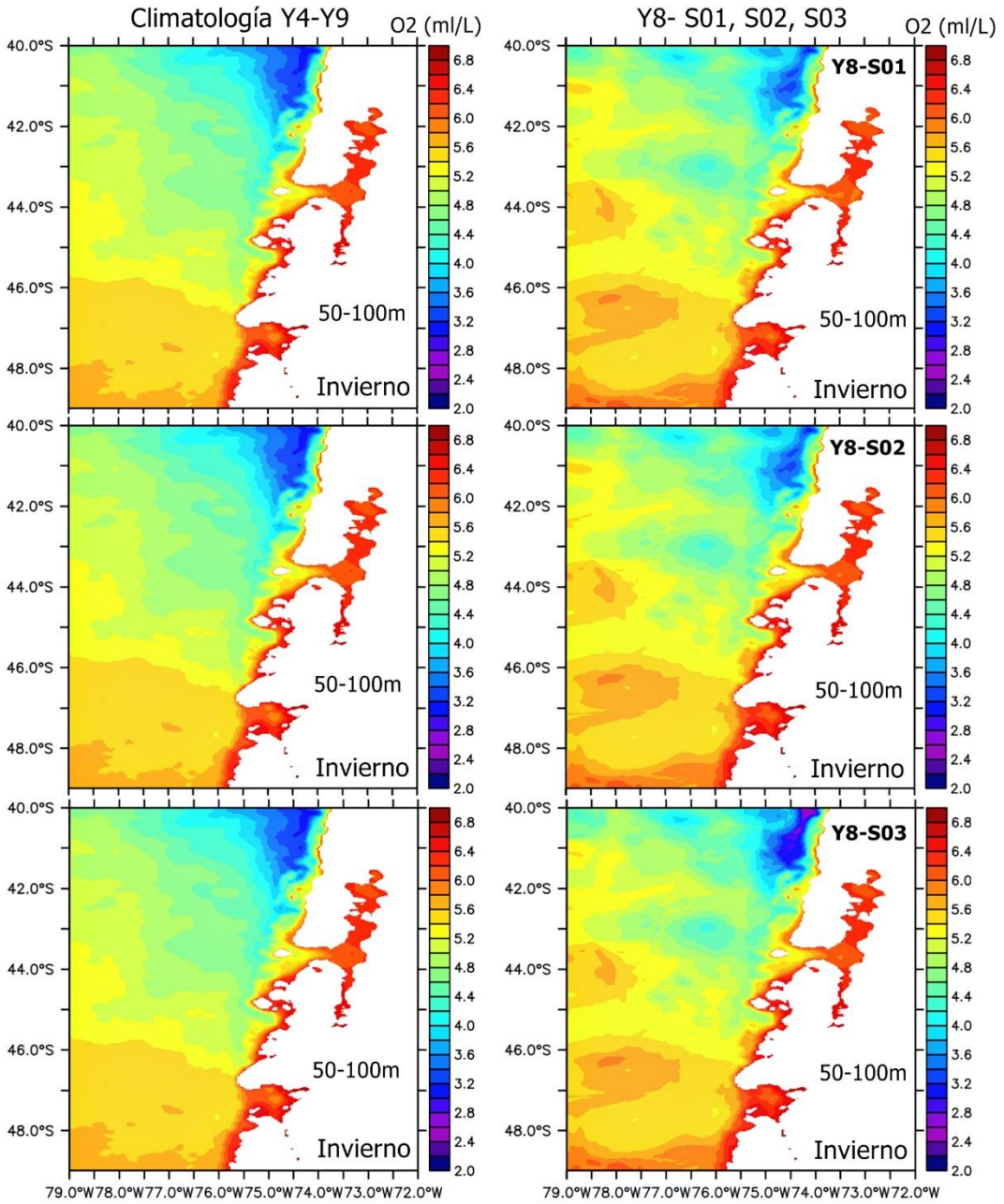
MOSA-PISCES Results- sensivity experiments



Sensivity S01

Sensivity S02

Sensivity S03



Sensivity S01

Sensivity S02

Sensivity S03