Summer school
Modelación Aplicada al Océano
Uso avanzado del modelo CROCO:
BIOGEOQUÍMICA
17-18 January 2022

# PISCES Parameters

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## Namelists PISCES

```
!!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
!! PISCES  :    1  - air-sea exchange                         (nampisext)
!! namelists    2  - biological parameters                    (nampisbio)
!!              3  - parameters for nutrient limitations      (nampislim)
!!              4  - parameters for phytoplankton             (nampisprod,nampismort)
!!              5  - parameters for zooplankton               (nampismes,nampiszoo)
!!              6  - parameters for remineralization          (nampisrem)
!!              7  - parameters for calcite chemistry         (nampiscal)
!!              8  - parameters for inputs deposition         (nampissed)
!!              9  - parameters for Kriest parameterization   (nampiskrp, nampiskrs)
!!              10 - additional 2D/3D  diagnostics            (nampisdia)
!!              11 - Damping                                  (nampisdmp)
!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
!''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''
&nampistrc     !   tracers definition
!,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
!
!              !    name    !           title of the field            !   units
!              !            !                                         !
!              !            !                                         !
   tracer(1)   = 'DIC      ' , 'Dissolved inorganic Concentration      ',  'mol-C/L'
   tracer(2)   = 'Alkalini' , 'Total Alkalinity Concentration         ',  'eq/L '
   tracer(3)   = 'O2       ' , 'Dissolved Oxygen Concentration         ',  'mol-C/L'
   tracer(4)   = 'CaCO3    ' , 'Calcite Concentration                  ',  'mol-C/L'
   tracer(5)   = 'PO4      ' , 'Phosphate Concentration                ',  'mol-C/L'
   tracer(6)   = 'POC      ' , 'Small organic carbon Concentration     ',  'mol-C/L'
   tracer(7)   = 'Si       ' , 'Silicate Concentration                 ',  'mol-C/L'
   tracer(8)   = 'PHY      ' , 'Nanophytoplankton Concentration        ',  'mol-C/L'
   tracer(9)   = 'ZOO      ' , 'Microzooplankton Concentration         ',  'mol-C/L'
   tracer(10)  = 'DOC      ' , 'Dissolved organic Concentration        ',  'mol-C/L'
   tracer(11)  = 'PHY2     ' , 'Diatoms Concentration                  ',  'mol-C/L'
   tracer(12)  = 'ZOO2     ' , 'Mesozooplankton Concentration          ',  'mol-C/L'
   tracer(13)  = 'BSi      ' , 'Diatoms Silicate Concentration         ',  'mol-C/L'
   tracer(14)  = 'Fer      ' , 'Dissolved Iron Concentration           ',  'mol-C/L'
   tracer(15)  = 'BFe      ' , 'Big iron particles Concentration       ',  'mol-C/L'
   tracer(16)  = 'GOC      ' , 'Big organic carbon Concentration       ',  'mol-C/L'
   tracer(17)  = 'SFe      ' , 'Small iron particles Concentration     ',  'mol-C/L'
   tracer(18)  = 'DFe      ' , 'Diatoms iron  Concentration            ',  'mol-C/L'
   tracer(19)  = 'DSi      ' , 'Sinking biogenic Silicate Concentration',  'mol-C/L'
   tracer(20)  = 'NFe      ' , 'Nano iron Concentration                ',  'mol-C/L'
   tracer(21)  = 'NCHL     ' , 'Nano chlorophyl Concentration          ',  'mol-C/L'
   tracer(22)  = 'DCHL     ' , 'Diatoms chlorophyl Concentration       ',  'mol-C/L'
   tracer(23)  = 'NO3      ' , 'Nitrates Concentration                 ',  'mol-C/L'
   tracer(24)  = 'NH4      ' , 'Ammonium Concentration                 ',  'mol-C/L'
/
!''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''''
```

# Phytoplankton parameters (default PISCES)

| Parameter | Units | Value | Description |
|---|---|---|---|
| $\mu^0_{max}$ | $d^{-1}$ | 0.6 | Growth rate at 0 °C |
| $\mu_{ref}$ | $d^{-1}$ | 1.0 | Growth rate reference for light limitation |
| $b_{resp}$ | $d^{-1}$ | 0.033 | Basal respiration rate |
| $b_P$ | – | 1.066 | Temperature sensitivity of growth |
| $\alpha^I$ | $(W\,m^{-2})^{-1}\,d^{-1}$ | 2; 2 | Initial slope of $P$–$I$ curve |
| $\delta^I$ | – | 0.05; 0.05 | Exudation of DOC |
| $\beta^I_1$ | – | 2.1; 1.6 | Absorption in the blue part of light |
| $\beta^I_2$ | – | 0.42; 0.69 | Absorption in the green part of light |
| $\beta^I_3$ | – | 0.4; 0.7 | Absorption in the red part of light |
| $K^{I,min}_{PO_4}$ | $nmol\,P\,L^{-1}$ | 0.8; 2.4 | Minimum half-saturation constant for phosphate |
| $K^{I,min}_{NH_4}$ | $\mu mol\,N\,L^{-1}$ | 0.013; 0.039 | Minimum half-saturation constant for ammonium |
| $K^{I,min}_{NO_3}$ | $\mu mol\,N\,L^{-1}$ | 0.13; 0.39 | Minimum half-saturation constant for nitrate |
| $K^{D,min}_{Si}$ | $\mu mol\,Si\,L^{-1}$ | 1 | Minimum half-saturation constant for silicate |
| $K_{Si}$ | $\mu mol\,Si\,L^{-1}$ | 16.6 | Parameter for the half-saturation constant |
| $K^I_{Si}$ | $\mu mol\,Si\,L^{-1}$ | 2; 20 | Parameters for Si / C |
| $K^{I,min}_{Fe}$ | $nmol\,Fe\,L^{-1}$ | 1; 3 | Minimum half-saturation constant for iron uptake |
| $S^I_{rat}$ | – | 3; 3 | Size ratio of Phytoplankton |
| $\theta^{Si,D}_m$ | $mol\,Si\,(mol\,C)^{-1}$ | 0.159 | Optimal Si / C uptake ratio of diatoms |
| $\theta^{Fe,I}_{opt}$ | $\mu mol\,Fe\,(mol\,C)^{-1}$ | 7; 7 | Optimal iron quota |
| $\theta^{Fe,I}_{max}$ | $\mu mol\,Fe\,(mol\,C)^{-1}$ | 40; 40 | Maximum iron quota |
| $m^I$ | $d^{-1}$ | 0.01; 0.01 | phytoplankton mortality rate |
| $w^P$ | $d^{-1}\,mol\,C^{-1}$ | 0.01 | Minimum quadratic mortality of phytoplankton |
| $w^D_{max}$ | $d^{-1}\,mol\,C^{-1}$ | 0.03 | Maximum quadratic mortality of diatoms |
| $\theta^{Chl,I}_{max}$ | $mg\,Chl\,(mg\,C)^{-1}$ | 0.033; 0.05 | Maximum Chl / C ratios of phytoplankton |
| $\theta^{Chl}_{min}$ | $mg\,Chl\,(mg\,C)^{-1}$ | 0.0033 | Minimum Chl / C ratios of phytoplankton |
| $I_{max}$ | $\mu mol\,C\,L^{-1}$ | 1; 1 | Threshold concentration for size dependency |

Aumont et al. (2015)

# Biomasa de Nanofitoplancton

$$\frac{\partial P}{\partial t} = (1-\delta^P)\boxed{\mu^P} P - m^P \frac{P}{K_m + P} P - \text{sh} \times w^P P^2 - g^Z(P)Z - g^M(P)M$$

growght

Grazing by micro and mesozoo

mortality

aggregation

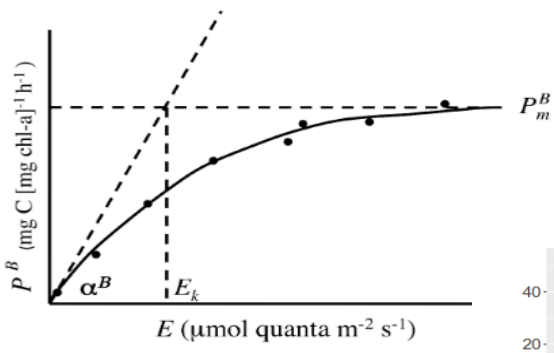
*PI curve= Photosynthetic response of phytoplakton to light*

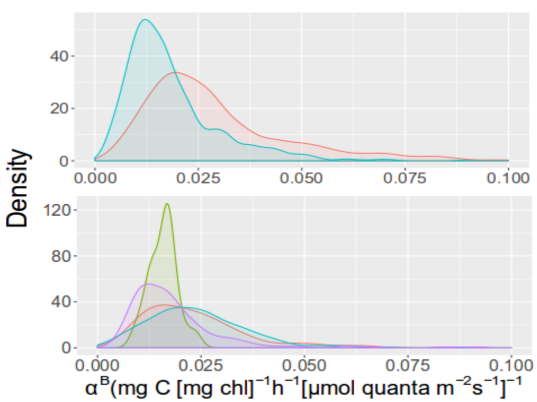
$\alpha^I$ $(\mathrm{W\,m^{-2}})^{-1}\,\mathrm{d}^{-1}$ 2; 2 Initial slope of $P$–$I$ curve

$$\mu^P = \mu_P f_1(L_{\text{day}}) f_2(z_{\text{mxl}}) \left(1 - \exp\left(\frac{-\alpha^P \theta^{\text{Chl},P} \text{PAR}^P}{L_{\text{day}}(\mu_{\text{ref}} + b_{\text{resp}})}\right)\right) L^P_{\text{lim}},$$

ln_newprod

$$\boxed{\mu^P} = \mu_P f_1(L_{\text{day}}) f_2(z_{\text{mxl}}) \left(1 - \exp\left(\frac{-\alpha^P \theta^{\text{Chl},P} \text{PAR}^P}{L_{\text{day}} \mu_P L^P_{\text{lim}}}\right)\right) L^P_{\text{lim}},$$




Ref: Aumont et al. (2015), Bouman et al. (2018)

## Phytoplankton parameters (default PISCES)

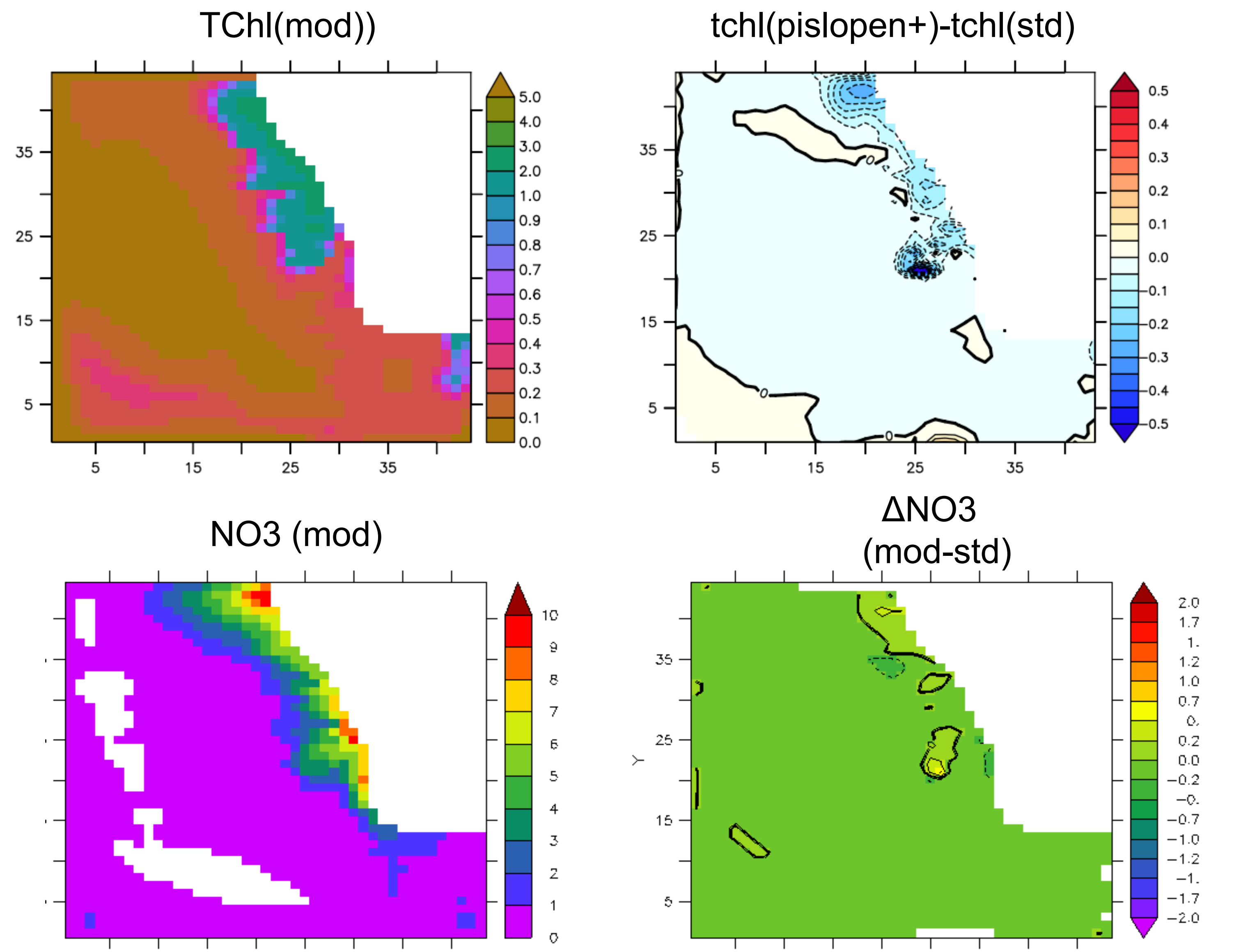
```
!!>>>>>>>>>>>>>
!! PISCES  :
!! namelists
```

```
4  - parameters for phytoplankton          (nampisprod,nampismort)
```

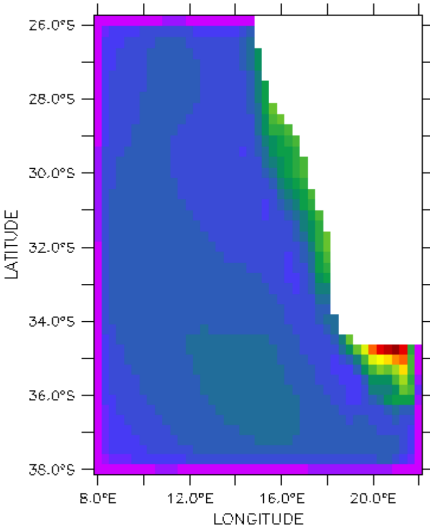
```
!-----------------------------------------------------------------------
&nampisopt     !   parameters for optics
!-----------------------------------------------------------------------
   parlux      =  0.43       ! Fraction of shortwave as PAR
/
!-----------------------------------------------------------------------
&namp4zprod    !   parameters for phytoplankton growth for PISCES std  - ln_p4z
!-----------------------------------------------------------------------
   pislopen    =  2.         ! P-I slope
   pisloped    =  2.         ! P-I slope  for diatoms
   xadap       =  0.         ! Adaptation factor to low light
   excretn     =  0.05       ! excretion ratio of phytoplankton
   excretd     =  0.05       ! excretion ratio of diatoms
   bresp       =  0.033      ! Basal respiration rate
   chlcnm      =  0.033      ! Maximum Chl/C in nanophytoplankton
   chlcdm      =  0.05       ! Maximum Chl/C in diatoms
   chlcmin     =  0.004      ! Minimum Chl/c in phytoplankton
   fecnm       =  80E-6      ! Maximum Fe/C in nanophytoplankton
   fecdm       =  80E-6      ! Maximum Fe/C in diatoms
   grosip      =  0.159      ! mean Si/C ratio
/
```

**Sensitivity to pislopen** (pislopen std=2; mod+=**+50%**)

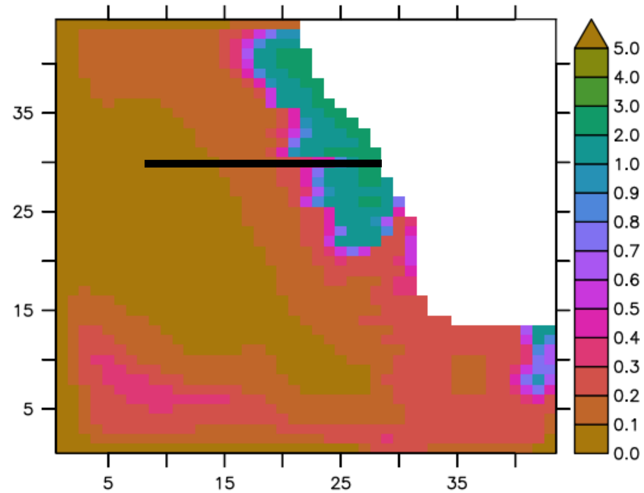
pislopen = control of nanophyto PP dependance to light



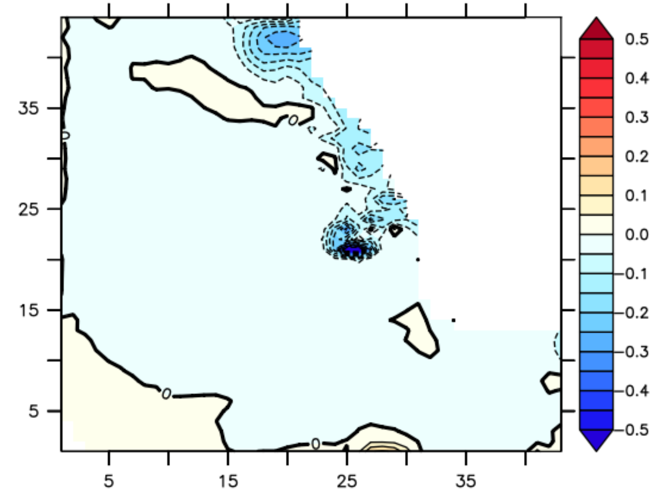
# **Sensitivity to pislopen** (std=2; mod+=**+50%**)



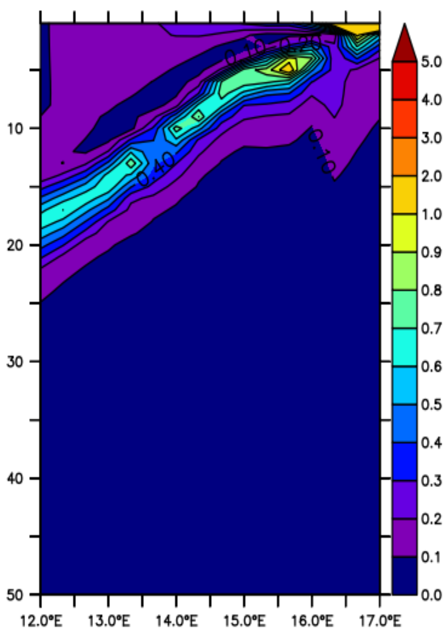

TChl(pislopen+)



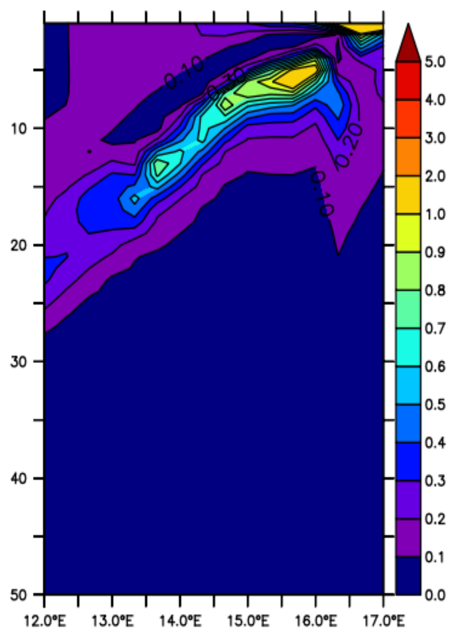

tchl(pislopen+)-tchl(std)



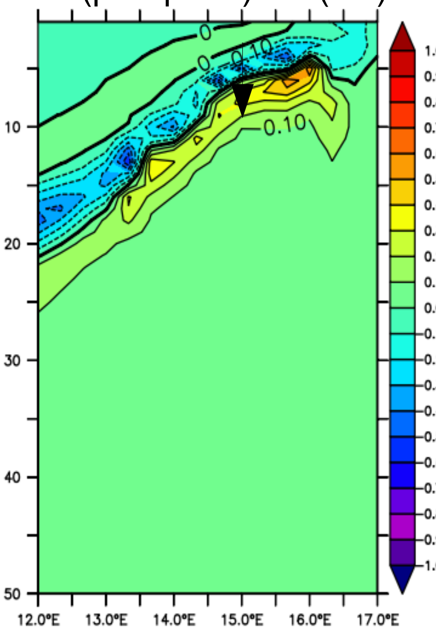

TChl-std




TChl(pislopen+)

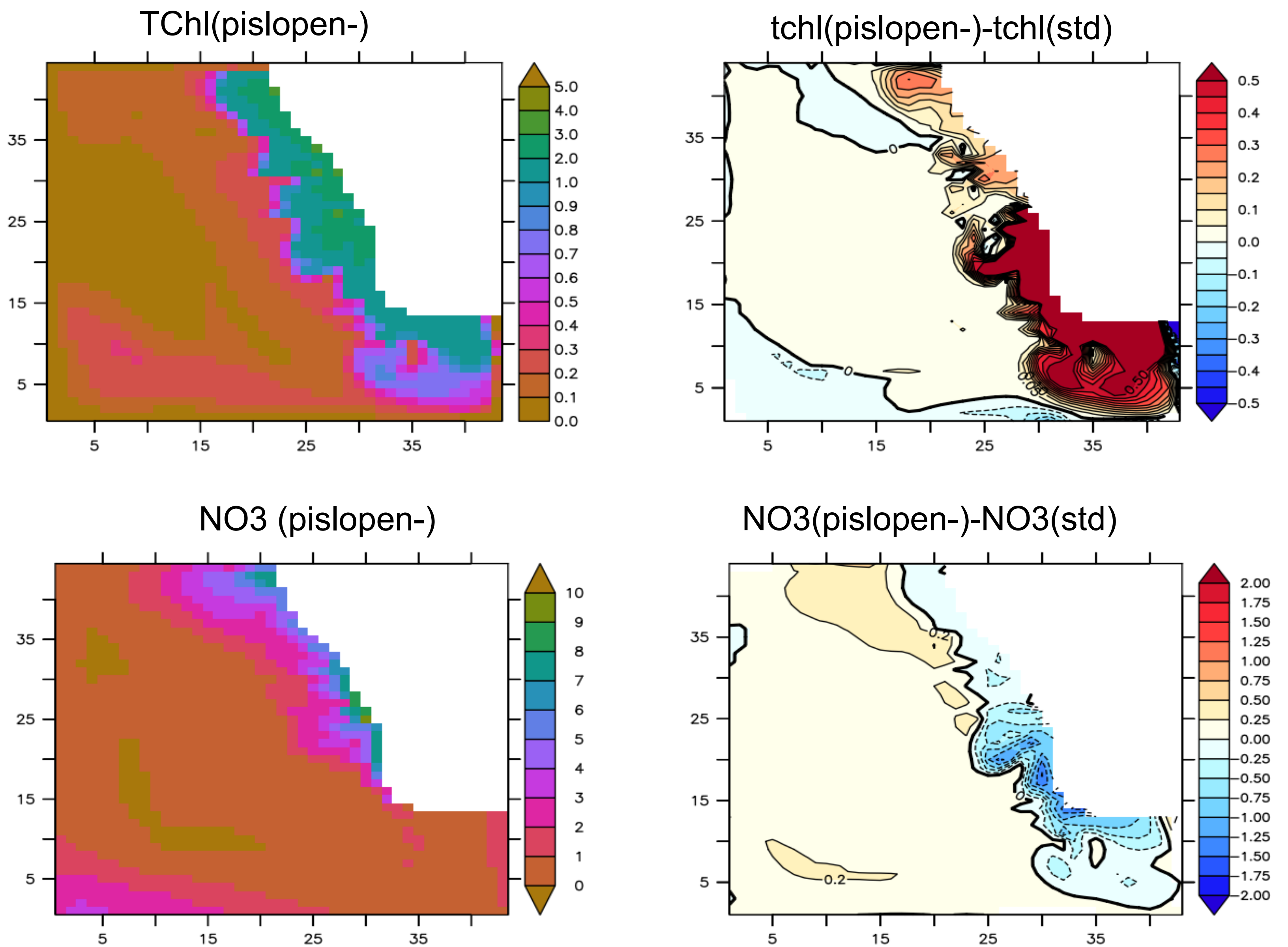



tChl(pislopen+)-tchl(std)

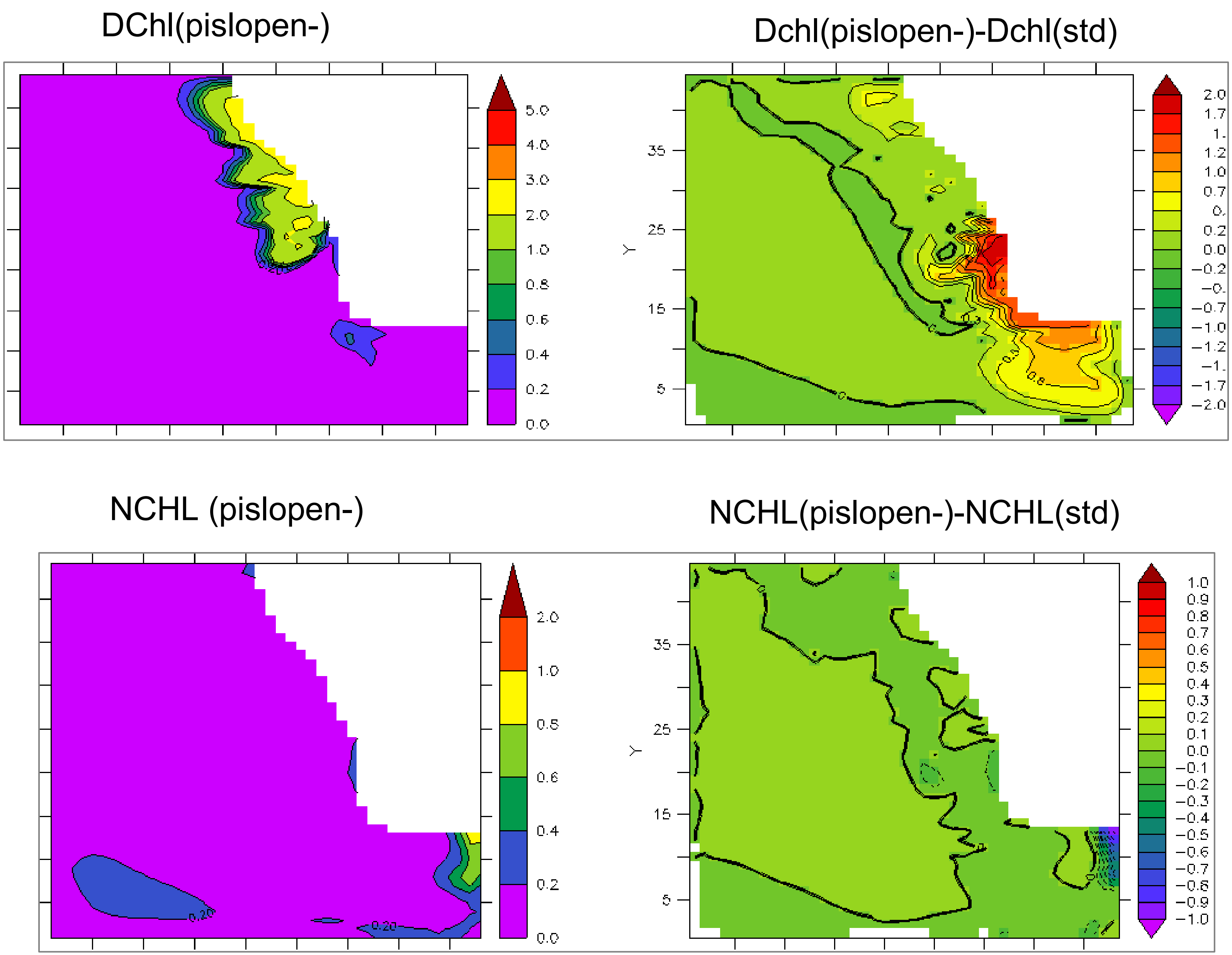



Deep Chlorophyll maximum is deeper when pislopen increases.
=> less light needed to create chl
=> reduction of light limitation

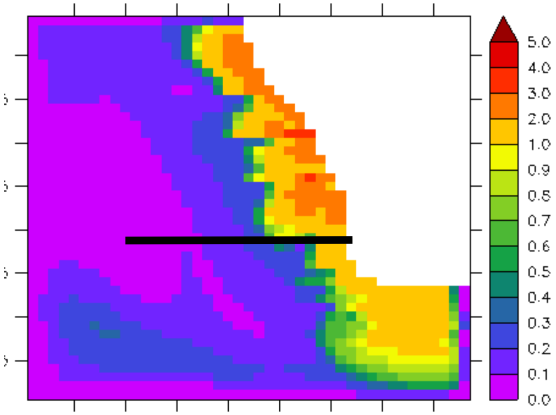
**Sensitivity to pislopen** (std=2; mod-=**-50%**)



**Sensitivity to pislopen** (std=2; mod-=**-50%**)

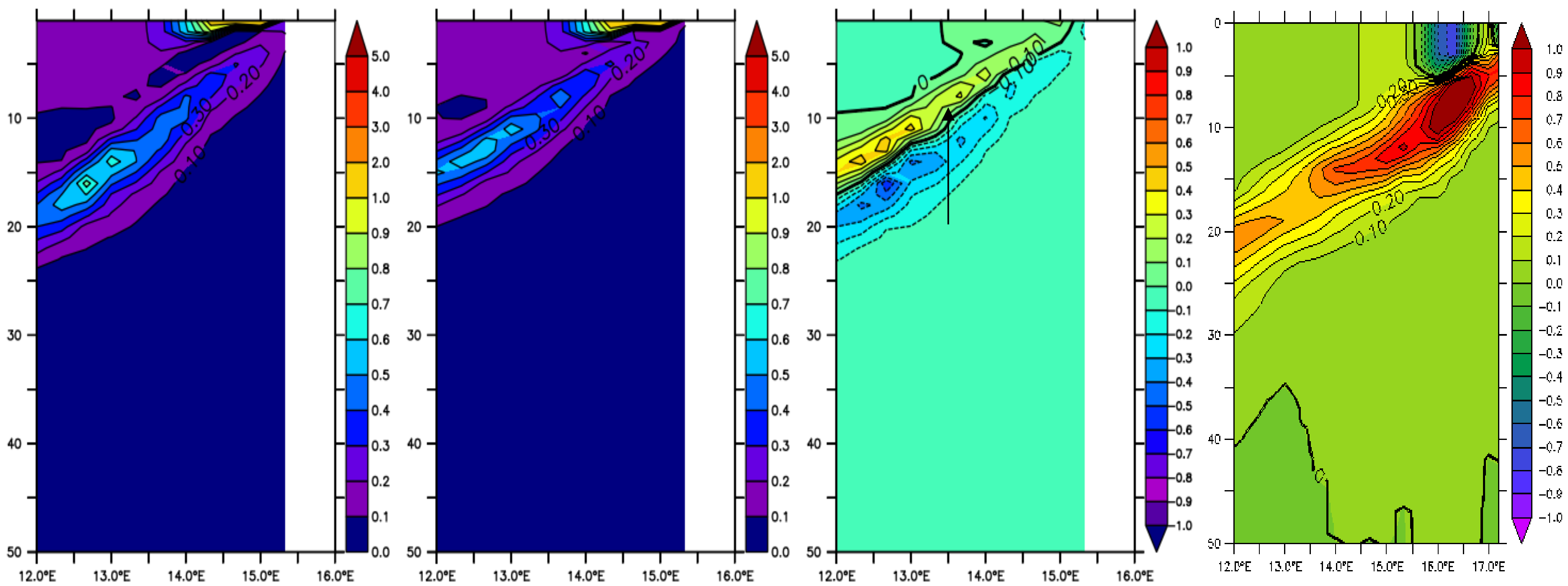


# **Sensitivity to pislopen** (std=2; mod-=1= **-50%**)



Diatom bloom: Why?
More light limitation in mod run
=> shallower DCM
=> more nitrate closer to the surface
=> incorporated in mixed layer => bloom

TChl (std) | TChl (mod) | ΔTChl (mod-std) | ΔNO3 (mod-std)



## Zooplankton parameters (default PISCES)

| Parameter | Units | Value | Description |
|---|---|---|---|
| $b_Z$ | – | 1.079; 1.079 | Temperature sensitivity term |
| $e^I_{\max}$ | – | 0.3; 0.35 | Maximum growth efficiency of zooplankton |
| $\sigma^I$ | – | 0.3; 0.3 | Non-assimilated fraction |
| $\gamma^I$ | – | 0.6; 0.6 | Excretion as DOM |
| $g^I_m$ | $d^{-1}$ | 3; 0.75 | Maximum grazing rate |
| $g^M_{FF}$ | $(m\,mol\,L^{-1})^{-1}$ | $2 \times 10^3$ | Flux feeding rate |
| $K^I_G$ | $\mu mol\,C\,L^{-1}$ | 20; 20 | Half-saturation constant for grazing |
| $p^I_P$ | – | 1; 0.3 | Preference for nanophytoplankton |
| $p^I_D$ | – | 0.5; 1 | Preference for diatoms |
| $p^I_{POC}$ | – | 0.1,0.3 | Preference for POC |
| $p^M_Z$ | – | 1.0 | Preference for microzooplankton |
| $F^I_{thresh}$ | $\mu mol\,C\,L^{-1}$ | 0.3; 0.3 | Food threshold for zooplankton |
| $J^Z_{thres}$ | $\mu mol\,C\,L^{-1}$ | 0.001 | Specific food thresholds for microzooplankton |
| $J^M_{thres}$ | $\mu mol\,C\,L^{-1}$ | 0.001 | Specific food thresholds for mesozooplankton |
| $m^I$ | $(\mu mol\,C\,L^{-1})^{-1}\,d^{-1}$ | 0.004; 0.03 | Zooplankton quadratic mortality |
| $r^I$ | $d^{-1}$ | 0.03,0.005 | Zooplankton linear mortality |
| $K_m$ | $\mu mol\,C\,L^{-1}$ | 0.2 | Half-saturation constant for mortality |
| $\nu^I$ | – | 0.5; 0.75 | Fraction of calcite that does not dissolve in guts |
| $\theta^{Fe,Zoo}$ | $\mu mol\,Fe\,mol\,C^{-1}$ | 10 | Fe / C ratio of zooplankton |

Aumont et al. (2015)

## Zooplankton parameters (default PISCES)

```
!!>>>>>>>>>>>>>
!! PISCES   :
!! namelists
```

```
5  - parameters for zooplankton                    (nampismes,nampiszoo)
```

```
!-----------------------------------------------------------------------
&namp5zmes      !   parameters for mesozooplankton
!-----------------------------------------------------------------------
   part2       =  0.75      ! part of calcite not dissolved in mesozoo guts
   grazrat2    =  0.75      ! maximal mesozoo grazing rate
   bmetexc2    =  .true.    ! Metabolic use of excess carbon
   resrat2     =  0.005     ! exsudation rate of mesozooplankton
   mzrat2      =  0.02      ! mesozooplankton mortality rate
   xpref2d     =  1.        ! zoo preference for phyto
   xpref2p     =  1.        ! zoo preference for POC
   xpref2z     =  1.        ! zoo preference for zoo
   xpref2m     =  0.2       ! meso preference for zoo
   xpref2c     =  0.3       ! zoo preference for poc
   xthresh2zoo = 1E-8       ! zoo feeding threshold for mesozooplankton
   xthresh2dia = 1E-8       ! diatoms feeding threshold for mesozooplankton
   xthresh2phy = 1E-8       ! nanophyto feeding threshold for mesozooplankton
   xthresh2mes = 1E-8       ! meso feeding threshold for mesozooplankton
   xthresh2poc = 1E-8       ! poc feeding threshold for mesozooplankton
   xthresh2     =  3E-7      ! Food threshold for grazing
   xkgraz2      =  20.E-6    ! half sturation constant for meso grazing
   epsher2      =  0.5       ! Efficicency of Mesozoo growth
   epsher2min   =  0.2      ! Minimum efficiency of mesozoo growth
   ssigma2      =  0.5      ! Fraction excreted as semi-labile DOM
   srespir2     =  0.2      ! Active respiration
   unass2c      =  0.3      ! non assimilated fraction of P by mesozoo
   unass2n      =  0.3      ! non assimilated fraction of N by mesozoo
   unass2p      =  0.3      ! non assimilated fraction of P by mesozoo
   grazflux    =  3.e3      ! flux-feeding rate
/
```

## Parámetros para Zooplancton (default PISCES)

$$\frac{\partial M}{\partial t} = e^M \left( g^M(P) + g^M(D) + g^M(\mathrm{POC}) + g_{\mathrm{FF}}^M(\mathrm{GOC}) + g_{\mathrm{FF}}^M(\mathrm{POC}) + g^M(Z) \right) M - m^M f_M(T) M^2 - r^M f_M(T) \left( \frac{M}{K_\mathrm{m} + M} + 3\Delta(\mathrm{O_2}) \right) M$$

grazing

mortality

$$g_m^Z = g_{\max}^{0,Z} f_Z(T)$$
$$f_Z(T) = b_Z^T,$$

*Secondary production*

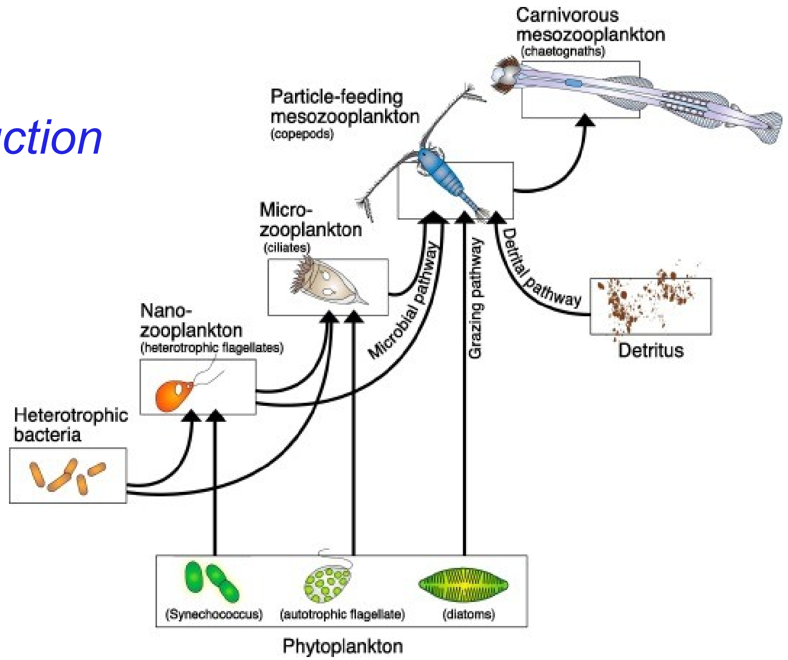
Grazing on each species $I$ is defined as

$$F = \sum_J p_J^Z \max\left(0, J - J_{\mathrm{thresh}}^Z\right)$$

$$F_{\mathrm{lim}} = \max\left(0, F - \min\left(0.5F, F_{\mathrm{thresh}}^Z\right)\right)$$

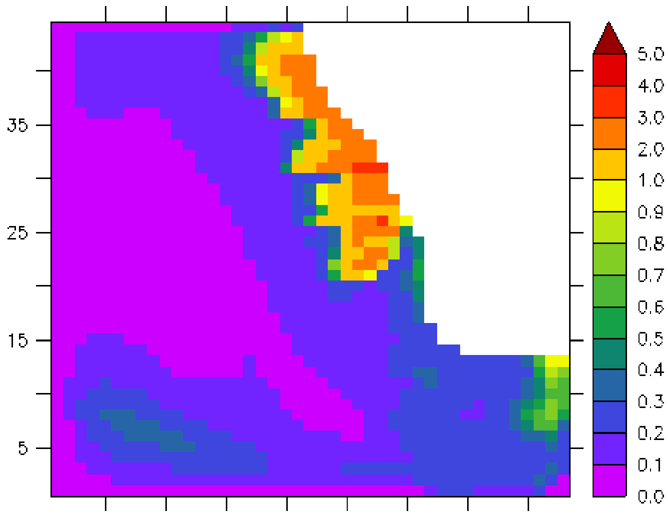
$$g^Z(I) = g_m^Z \frac{F_{\mathrm{lim}}}{F} \frac{p_I^Z \max\left(0, I - I_{\mathrm{thresh}}^Z\right)}{K_\mathrm{G}^Z + \sum_J p_J^Z J}, \qquad (26a)$$

where $J$ denotes all the species microzooplankton can graze upon ($P$, $D$ and POC) and $p_J^Z$ is the preference microzooplankton has for each $J$. In PISCES, we have chosen

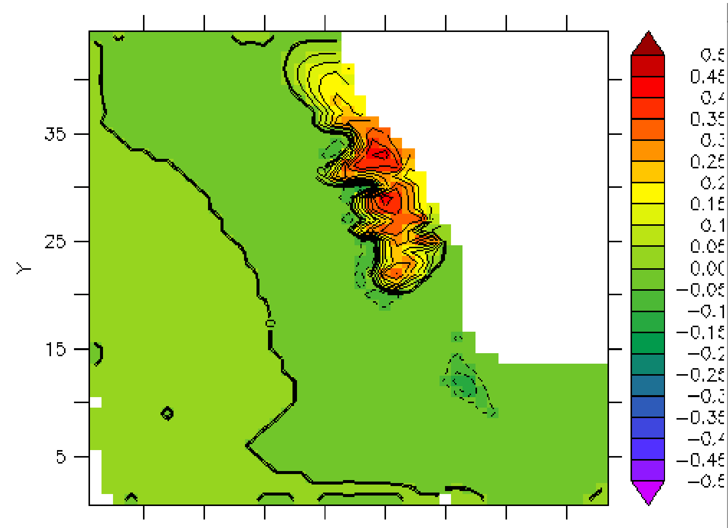


# Sensitivity on grazing coefficient of mesozooplankton

Chl( grazrat2 -50%, grazrat2 std =0.75 )

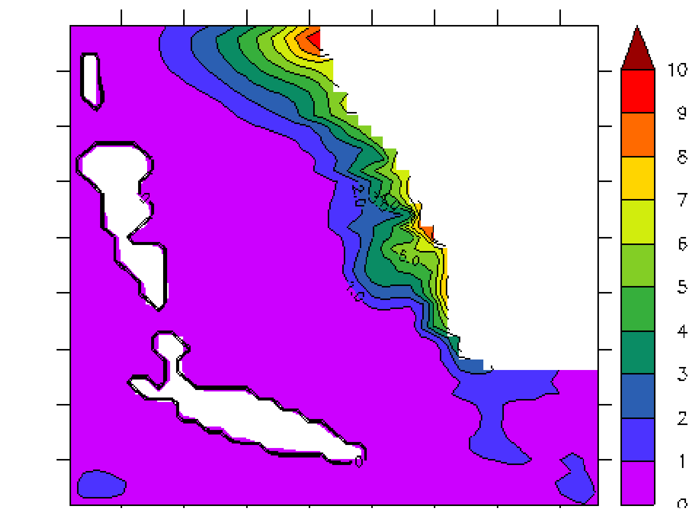



chl(grazrat2 -50%)-chl(std)

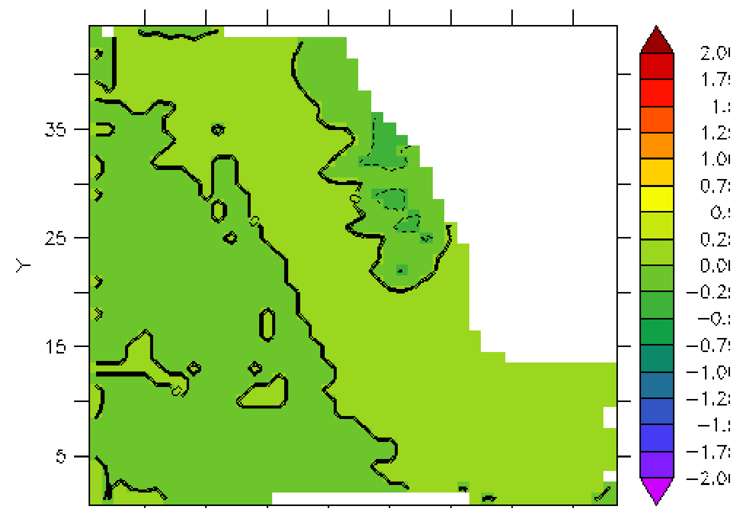



Increase of Chl
=> limitation of
phyto by grazing

NO3( grazrat2 -50%, grazrat2 std =0.75 )



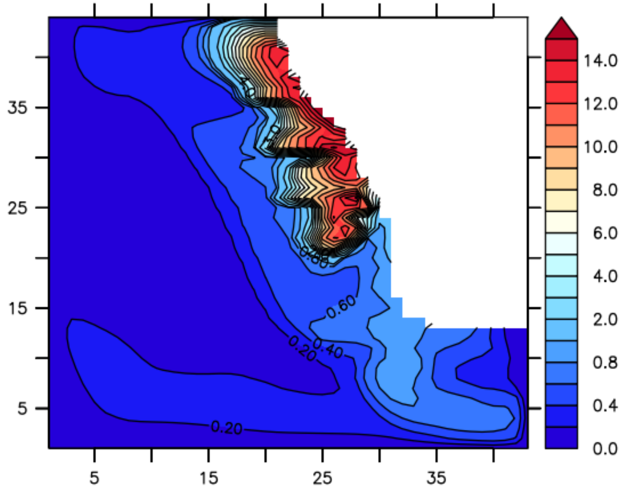

NO3(grazrat2 -50%)-NO3(std)



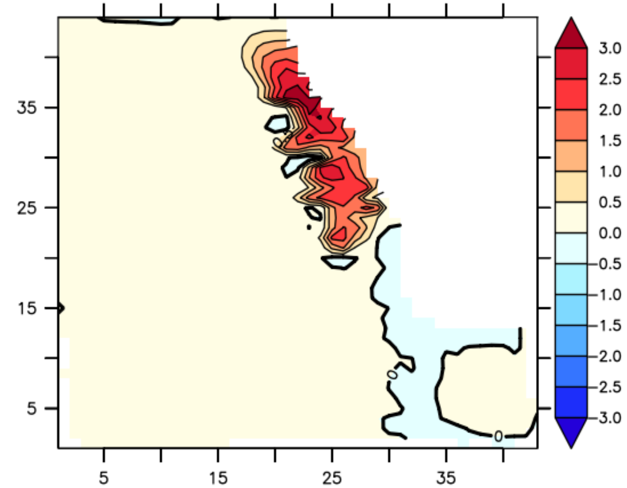

Slight decrease of NO3 because of increased consumption by diatoms

# Sensitivity on grazing coefficient of mesozooplankton

Diatoms( grazrat2 -50%, grazrat2 std =0.75 )

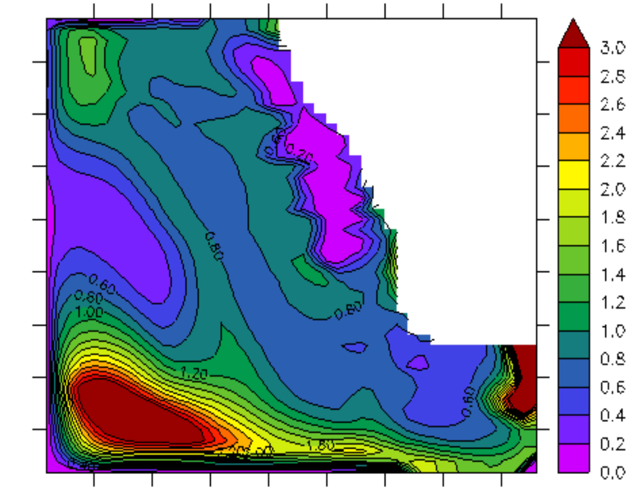



Diatoms(grazrat2 -50%)-MesoZ(std)

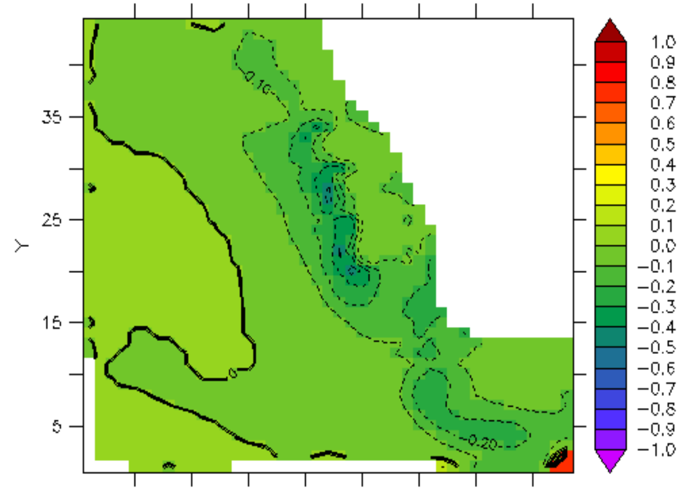



increase of diatoms because of decrease of grazing by mesoZoo on diatoms

nanoPhy( grazrat2 -50%, grazrat2 std =0.75 )



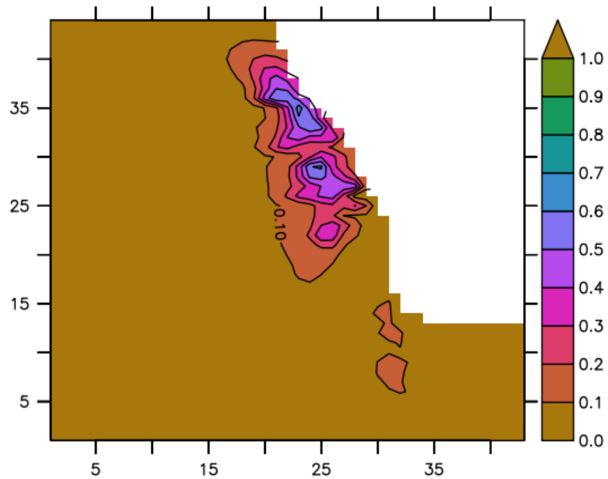

nanoPhy(grazrat2 -50%)-nanoPhy(std)



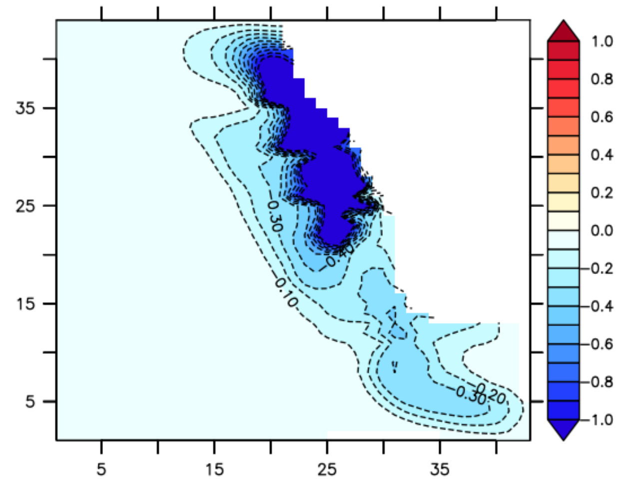

decrease of nanoPhy because of increase of μZoo grazing on nanoPhy

## Sensitivity on grazing coefficient of mesozooplankton

MesoZoo( grazrat2 -50%, grazrat2 std =0.75 )

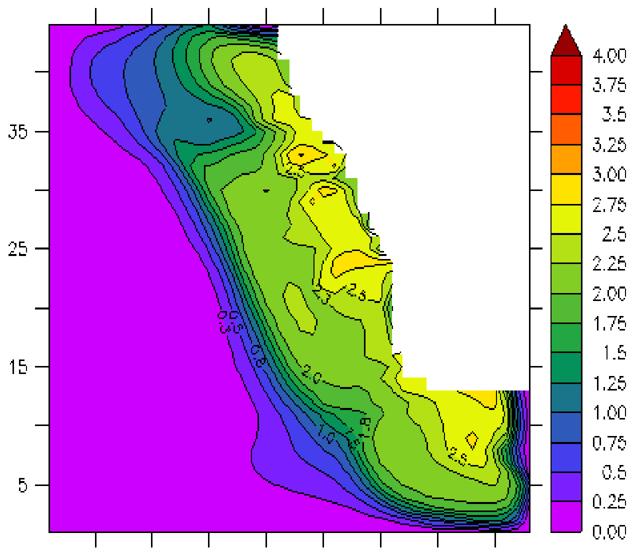



MesoZ(grazrat2 -50%)-MesoZ(std)

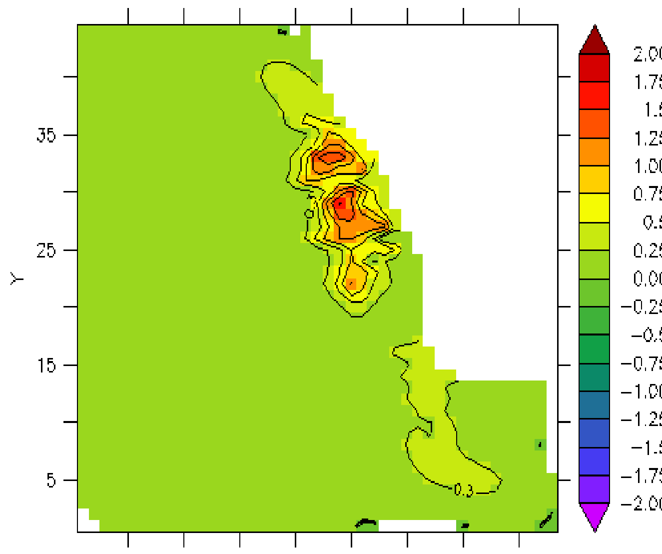



decrease of mesoZoo because of decrease of grazing

μZoo( grazrat2 -50%, grazrat2 std =0.75 )




μZoo(grazrat2 -50%)-μZoo(std)




Increase of μZoo because of decrease of mesoZoo grazing on μZoo

## Boolean variables

**Table 2.** Boolean variables in the namelist. These variables activate functionalities of PISCES.

| Boolean name | Description |
|---|---|
| ***ln_co2int*** | Read atmospheric pco2 from a file (T) or constant (F) |
| ***ln_presatm*** | Constant atmospheric pressure (F) or from a file (T) |
| ***ln_varpar*** | PAR made a variable fraction of shortwave (T) or not (F) |
| ***ln_newprod*** | Use Eq. (2a) (T) or Eq. (2b) for phytoplankton growth |
| ***ln_dust*** | Dust input from the atmosphere (T) |
| ***ln_solub*** | Variable solubility of iron in dust (T) |
| ***ln_river*** | River discharge of nutrient (T) |
| ***ln_ironsed*** | Sedimentary source of iron (T) |
| ***ln_ironice*** | iron input from sea ice (T) |
| ***ln_hydrofe*** | iron input from hydrothermalism (T) |
| ***ln_pisdmp*** | Relaxation of some tracers to a mean value (T) * |
| ***ln_check_mass*** | Check mass conservation (T) |

## Parámetros para DOM (default PISCES)

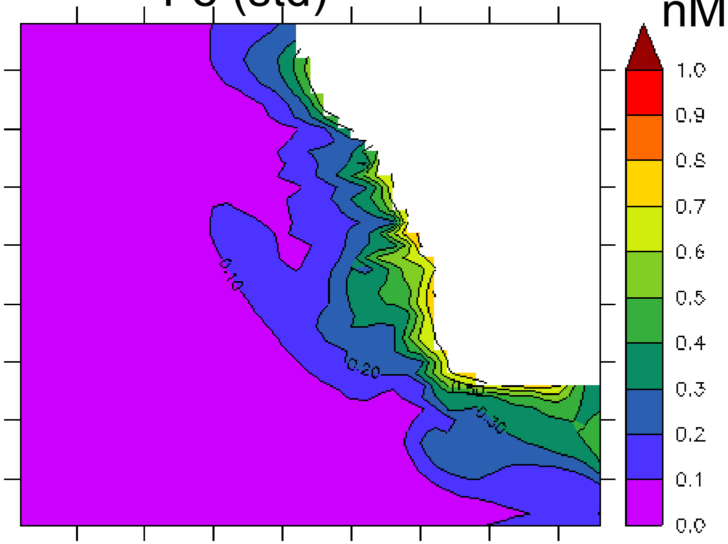
```
!!>>>>>>>>>>>>>
!! PISCES  :
!! namelists
```

```
8  - parameters for inputs deposition          (nampissed)
```

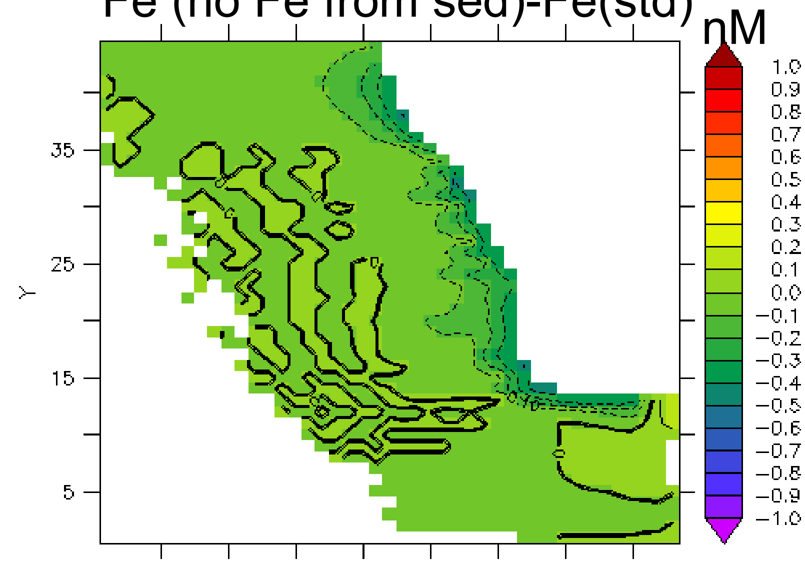
```
!
&nampissbc      !   parameters for inputs deposition
!,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
   ln_dust      =  .true.    ! boolean for dust input from the atmosphere
   ln_river     =  .false.   ! boolean for river input of nutrients
   ln_ndepo     =  .false.    ! boolean for atmospheric deposition of N
   ln_ironsed   =  .true.    ! boolean for Fe input from sediments
   sedfeinput   =  2E-9      ! Coastal release of Iron
   dustsolub    =  0.014     ! Solubility of the dust
   mfrac        =  0.035     ! Fe mineral fraction of dust
   wdust        =  2.0       ! Dust sinking speed
   diazolight   = 50         ! Diazotrophs sensitivity to light (W/m2)
   nitrfix      = 1.E-7      ! Nitrogen fixation rate
   concfediaz   = 1.E-10     ! Diazotrophs half-saturation Cste for Iron
/
```

**Sensitivity on Fe input from sediment** (mod=no sed input)

Fe (std)

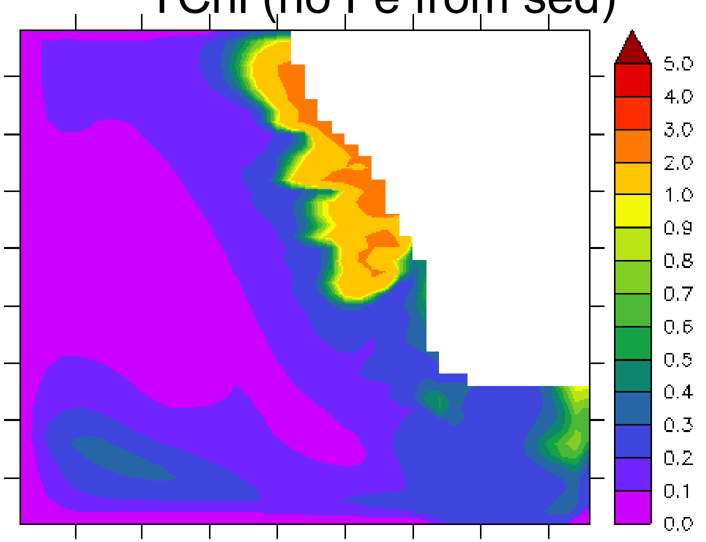



Fe (no Fe from sed)-Fe(std)

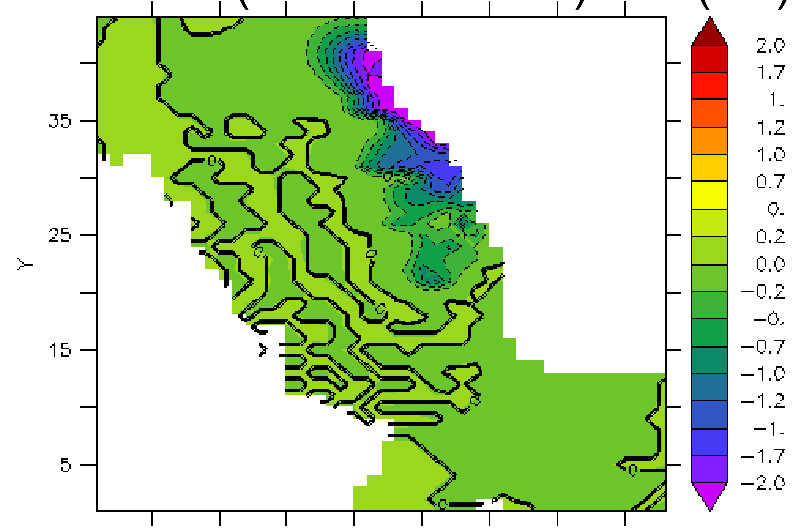



Fe decrease

TChl (no Fe from sed)



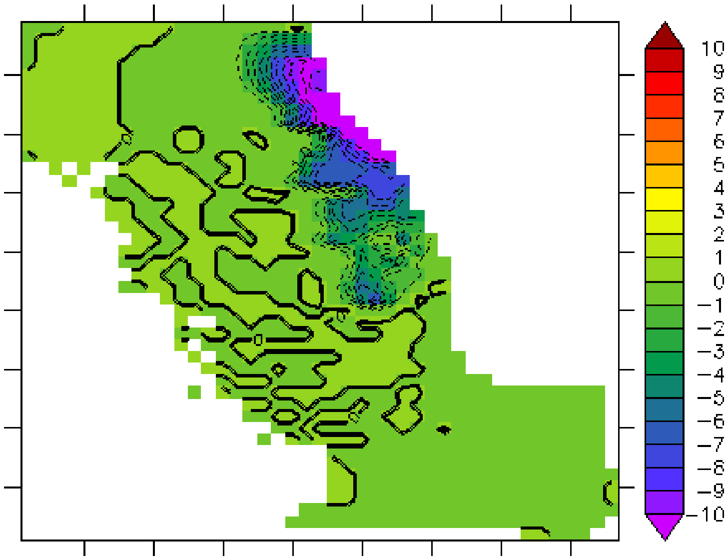

TChl (no Fe from sed)-Tchl(std)



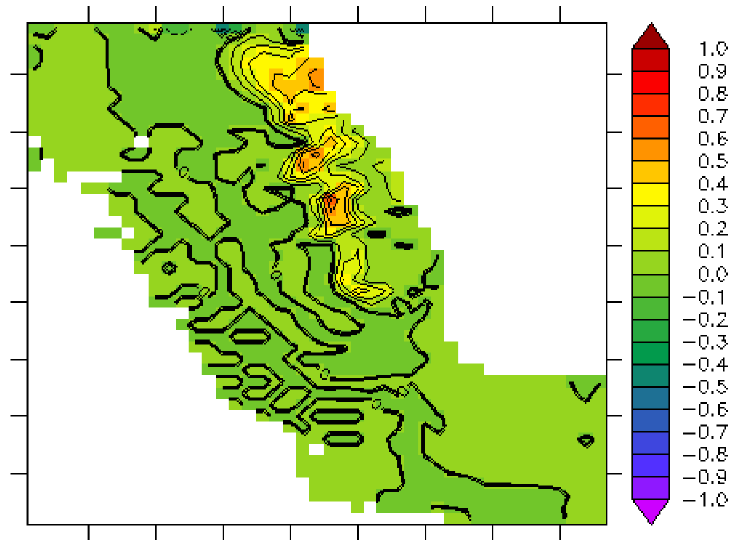

Chl decrease because iron becomes limiting instead of nitrate + diatoms need a lot of Iron

# Sensitivity on Fe input from sediment

Diatoms (no Fe from sed)-Dia(std)



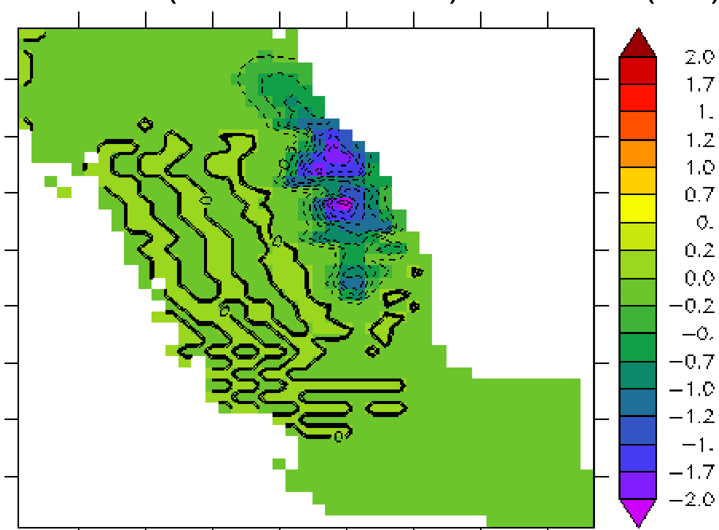

nanoPhy(no Fe from sed)-nanoPhy(std)



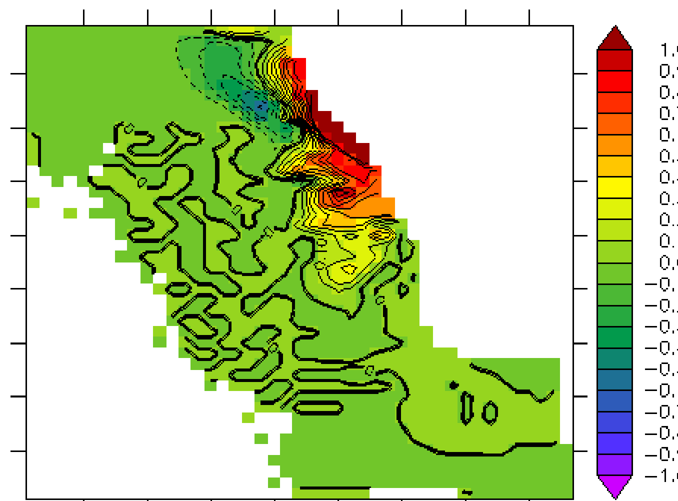

(left) Dia decrease because of Fe limitation

(right) NanoPhy increase because less Fe needed and less grazed by MesoZoo

MesoZoo (no Fe from sed)-MesoZoo(std)




µZoo (no Fe from sed)-µZoo(std)




(left) MesoZoo decrease because less prey (mainly Dia, prey decrease not compensated by µZoo increase)

(right) µZoo increase because more prey (nanophy) and less grazed by mesoZoo