A focus in the North Atlantic in the ORCA05-PISCES experiment

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1 Introduction

The global coupled biogeochemistry-dynamics experiment ORCA05-PISCINT3 has shown to have several problems in the North Atlantic. Biogeochemical models like PISCES have a great sensitivity to the dynamics, so that small discrepancies between the model and the real ocean can produce big errors in the biogeochemical variables. The purpose of this report is to document the errors in two fields (nutrients, chlorophyll) and to try to relate them, if possible, to errors in the physical variables (temperature, salinity, density). We will also compare the physics of this ORCA05 simulation (ORCA global grid at 1/2 degree) with simulations at higher resolution carried on by the DRAKKAR project (ORCA025 and NATL12).

ORCA05-PISCINT3 is an experiment forced using ERA40. The total length is 48 years, from 1958 to 2001. The PISCES model is run "online". Initial conditions for tracers are derived from the World Ocean Atlas (Levitus, 2005). For the biogeochemical variables, we have chosen to work with an interannual mean of each month in order to keep the seasonal cycle. The period of interest is 1996-2000, chosen because it is far enough from the begining of the run to avoid spin-up or ajustements effects and long enough to avoid a singularity of a particuliar year. All the figures presented here are means of $1996 - 2000$ and, for clarity, we chose to focus on some relevant month (march, april, may and august) rather than all the months.

Section 2 is a comparison of surface chlorophyll with data from SEAWIFS, section 3 deals with the mixed layer depth compared to the climatology based on ARGO floats done by Clément de Boyer Montégut. In section 4, we compare the temperature and nitrates with data from the World Ocean Atlas. Finally, section 5 is a comparison with one of the DRAKKAR runs ORCA05-G70.114 and we focus on the differences in the dynamics. Additional figures are provided in 4 annexes. Annex 1 shows results from a Mercator simulation using degraded fields of ORCA025 and PISCES offline. Annex 2 deals with the differences in SST and SSS compared to World Ocean Atlas. Annex 3 focus on the oxygen at 100 meters and along sections. Annex 4 are chlorophyll plots with a linear scale for readers who does not feel comfortable with the logarythmic scale used in section 2. Finally, Annex 5 is the namelist of ORCA05-PISCINT3.

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2 Comparaison of chlorophyll with SEAWIFS

In this section, we compare the mean surface chlorophyll from the ORCA05-PISCINT3 model with a climatology based on Seawifs, computed with data of years 1999 to 2005. Figures 1 and 2 are surface maps of the decimal logarithm of chlorophyll concentration in $mg.m^{-3}$, figure 3 shows surface chlorophyll concentration along zonal sections at 30°N and 40°N in the model and in the climatology. Maps of surface chlorophyll concentration with a linear scale are available in annex.

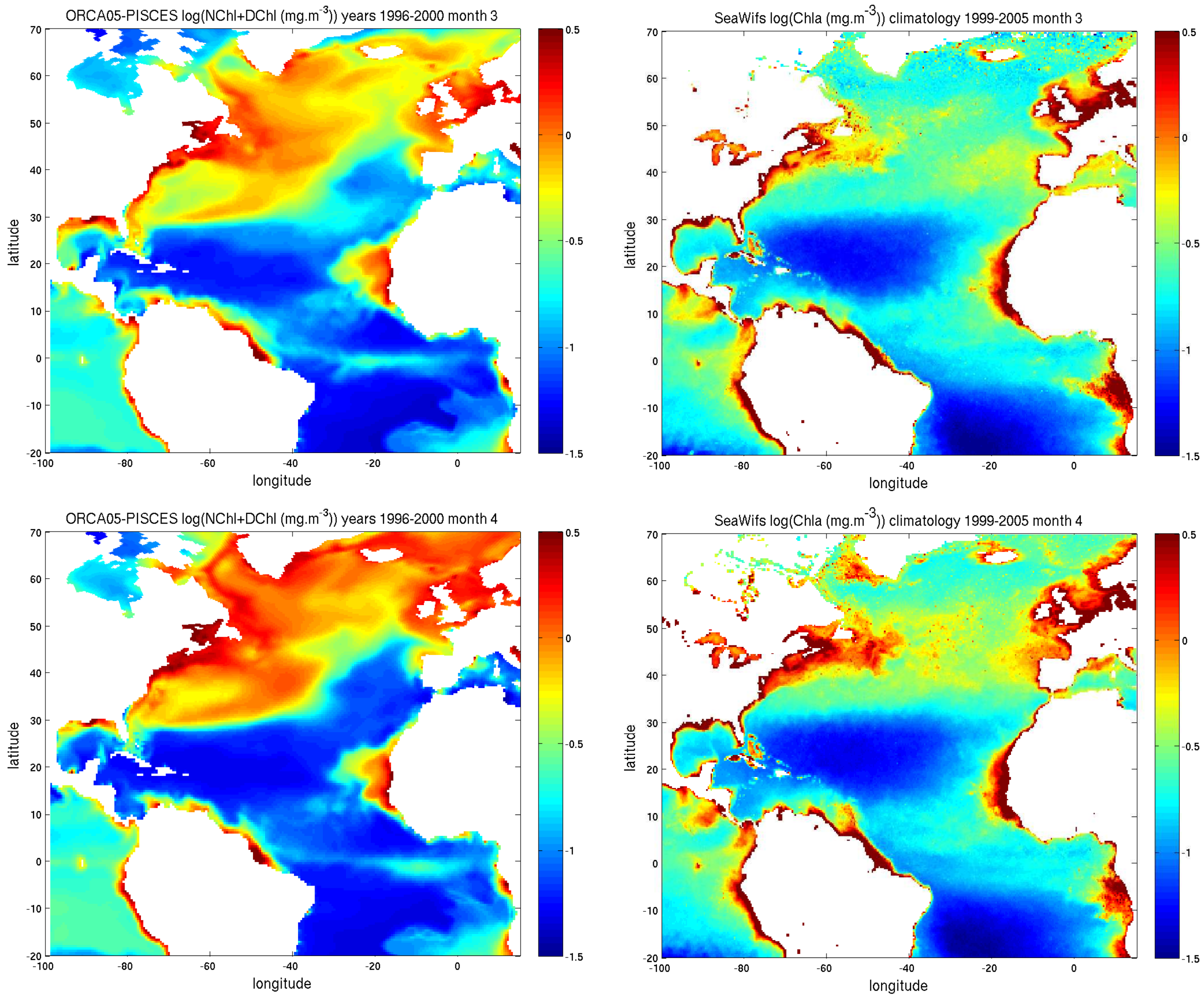

Figure 1: Mean surface chlorophyll in ORCA05-PISCES years 1996-2000 compared with Seawifs climatology in march and april

Chlorophyll concentration is a relevant measurement of the biological activity in the ocean (Figs. 1 and 2, right panels). At mid-latitudes in the North Atlantic, the spring bloom appears north of a latitude around 30-40°N . In march, april and may, data show a clear meridional gradient of chlorophyll located at a latitude that migrates gradually to the north. In august, high chlorophyll is limited to the subpolar gyre (north of 50°N). The model fails to reproduce this feature. We can see that, although the model has stronger values north of 50°N , there is a permanent deficit in chlorophyll at mid-latitudes in the eastern part of the basin (30°W - 10°W and 30°N -50°N). In fact, the North-East Atlantic is completely oligotrophic in the model in the region. between the subtropical and the subpolar gyres. On the other hand, there is too much chlorophyll in the western part of the basin.

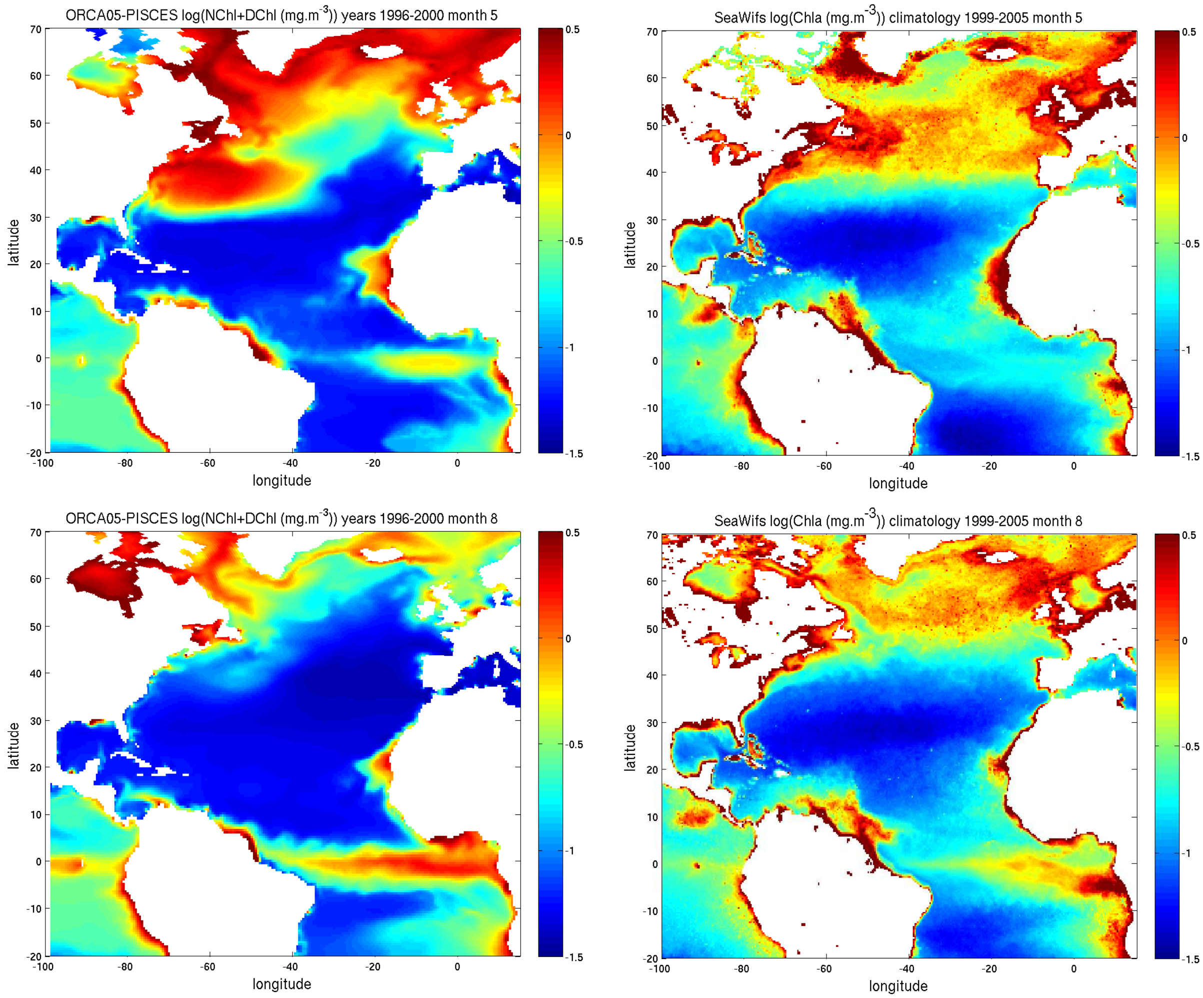

Figure 2: Mean surface chlorophyll in ORCA05-PISCES years 1996-2000 compared with Seawifs climatology in may and august

The model overestimates considerably the chlorophyll gradient from the west (too productive) to the east (too oligotrophic), so we have plotted in Fig.3 zonal sections at 30°N and 40°N to quantify the model-data differences (with a linear scale for chlorophyll). At 30°N observations (blue curves) show a uniform concentration, larger in march and decaying after spring. In contrast the model (red curve) has a larger concentration in the west with an unrealistic east-west gradient. Chlorophyll is always too low in the east. A striking feature is the absence of the concentration maximum (due to the upwelling along the portugal coast) in the model, which contrasts with the good agreement between the model and SEAWIFS in the other great upwelling systems. At 30°N (black curve) observations show large concentrations in the west, a sharp gradient west of 60°W , and then a zonally uniform concentration up to the coastal maximum in the east. The model (magenta curve) creates a spurious gradient in the middle of the basin, with concentrations that fall way below the observed east of 30°W , and again the coastal signal is missing.

The aim of the following figures is to investigate these discrepancies: are they due to the dynamics? If so, is it a problem with the mixed layer depth, the circulation, or with the nutrient supply?

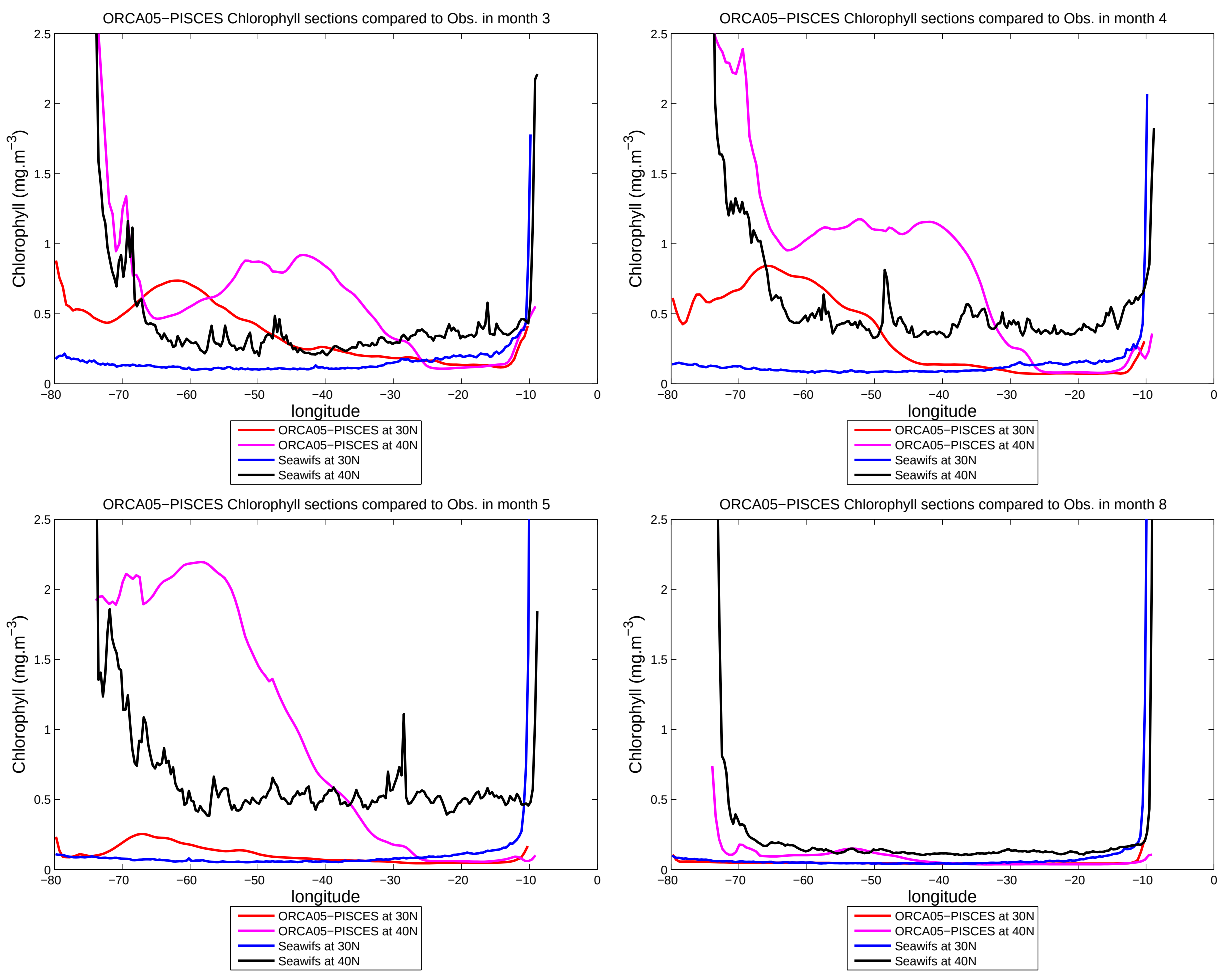

Figure 3: Mean surface chlorophyll in ORCA05-PISCES years 1996-2000 compared with Seawifs climatology in march, april, may and august

3 Comparaison of mixed layer depth with Clement de Boyer Montegut climatology

In this section, we compare the mixed layer depth with a climatology based on ARGO floats computed by Clément de Boyer Montégut (de Boyer Montegut et al, ...). Figures 4 and 5 are maps of the mixed layer depth, saturated at 150 meters to emphasize the shallow mixed layers in spring and summer. Figure 6 shows the mixed layer depth along zonal sections at 30 °N and 40 °N in the model and in the climatology, similar to Fig.3.

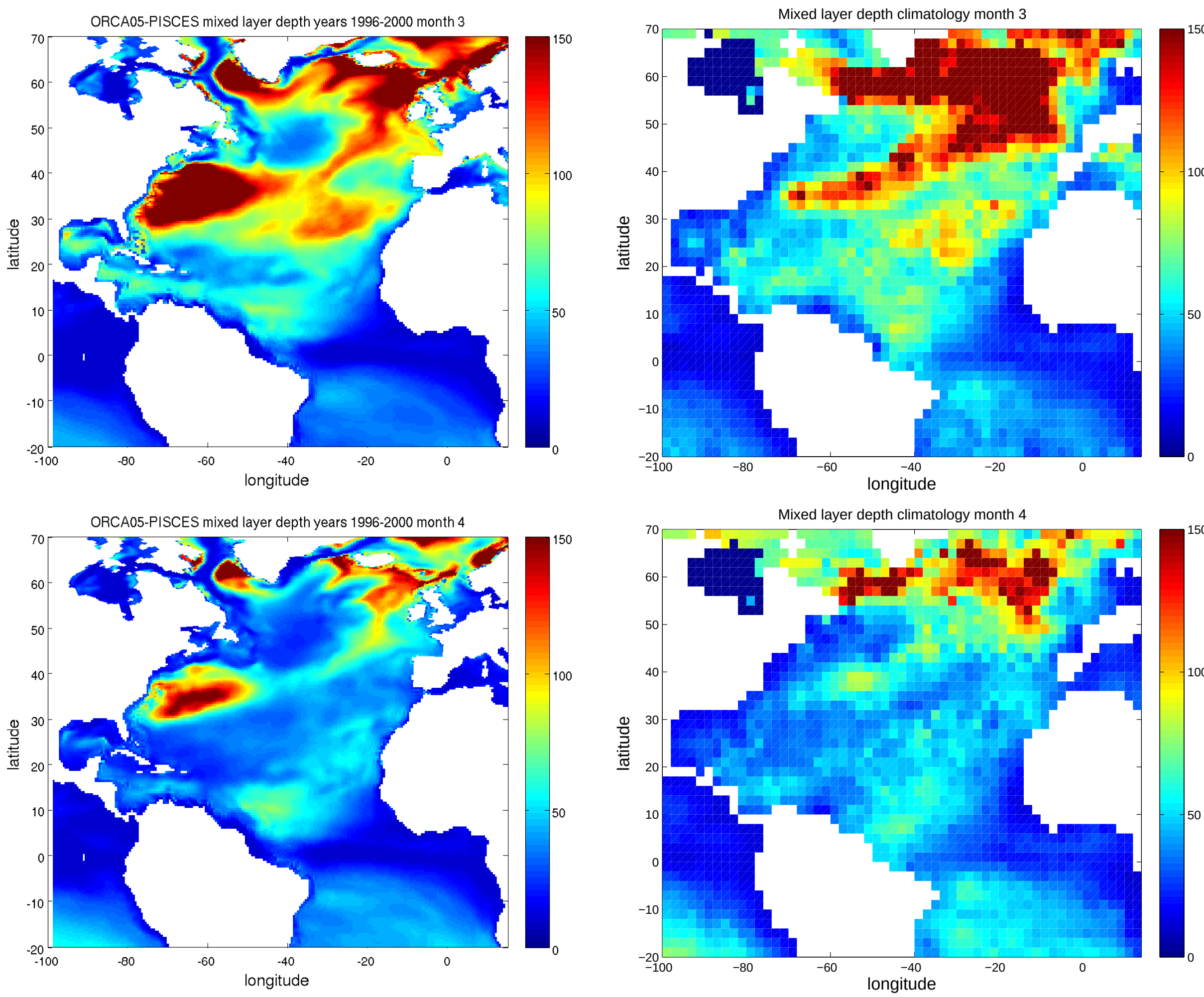

Figure 4: Mixed Layer Depth in ORCA05-PISCES years 1996-2000 compared with climatology in march and april

In march and april, we can see that there is a too deep mixed layer at mid-latitude in the western part of the basin. Values in the model reach 200 meters in march whereas the observation are roughly 50 meters. The reason for this discrepancy could be a misrepresentation of surface fluxes, or the lack of eddies that tend to restratify the mixed layer. In the eastern part of the domain, values in the model have the same order of magnitude than in the observations though some local extrema are not well represented. In may, we have a quite good agreement and the mixed layer is shallower in the model, excepted at 30 °N between 38 °W and 20 °W . In august, the model has almost everywhere a shallower mixed layer than observations, shallower by a factor of roughly 1.5 except in a small area in the west on the 40 °N section.

Generally, the model and observations are in a quite good agreement. Deficiencies of the mixed layer depth do not seem to explain the problem with the primary production.

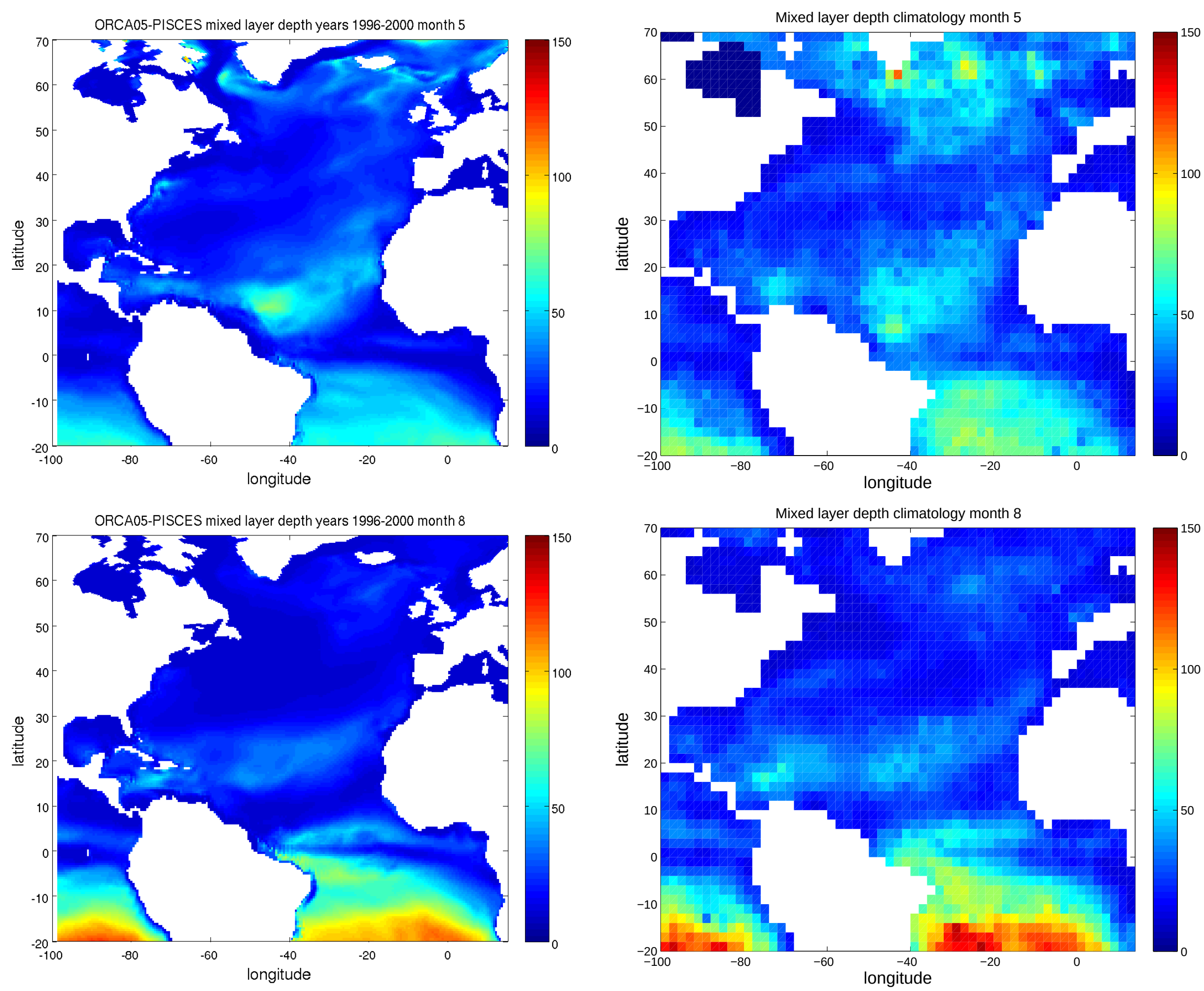

Figure 5: Mixed Layer Depth in ORCA05-PISCES years 1996-2000 compared with climatology in may and august

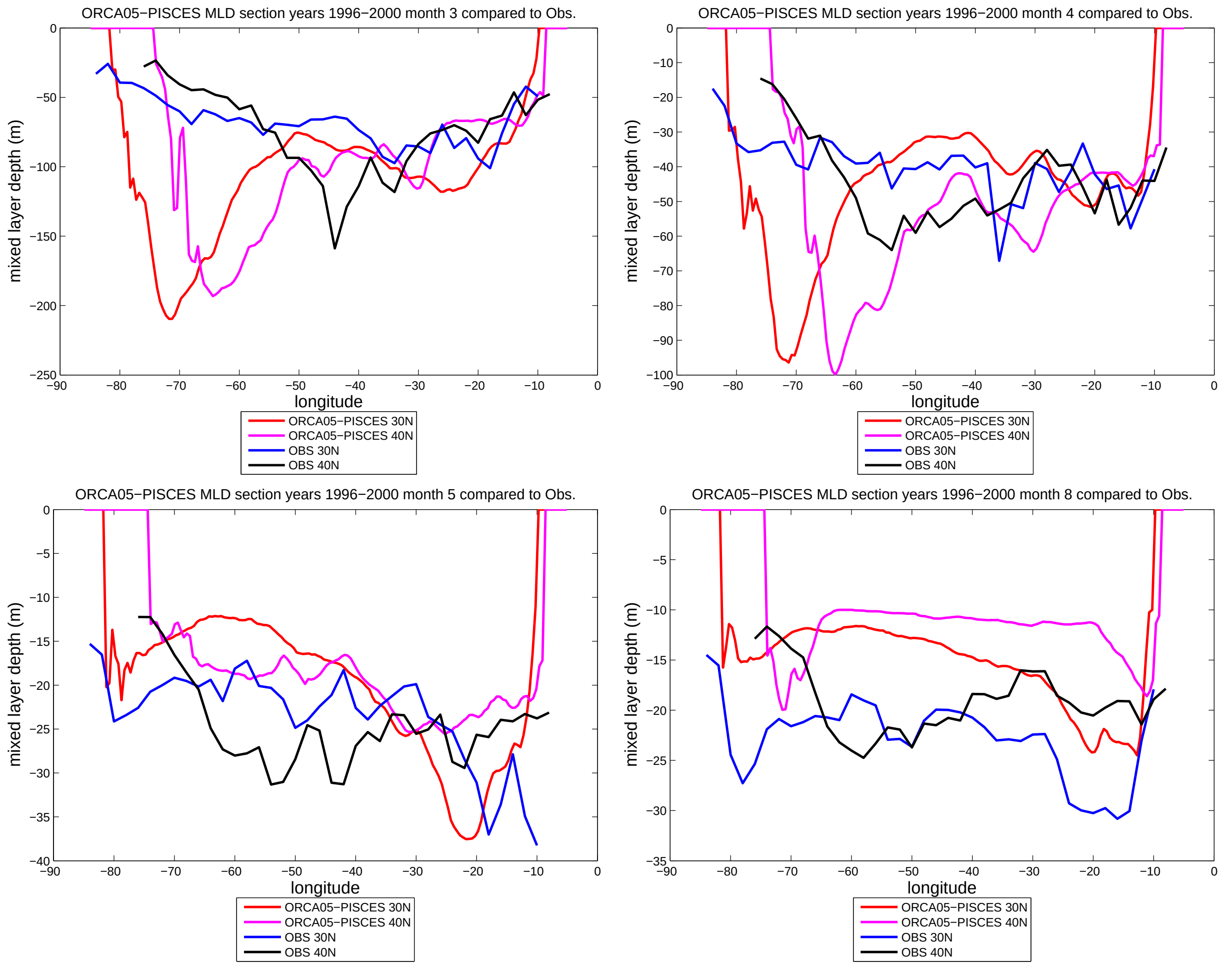

Figure 6: Mixed Layer Depth in ORCA05-PISCES years 1996-2000 compared with climatology in march, april, may and august

4 Comparaison of temperature and nitrates sections with World Ocean Atlas

In this section, we compare sections of temperature and nitrates concentration with the World Ocean Atlas at 30°N in march (fig. 7) and august (fig. 8) then at 40°N in march (fig. 9) and august (fig. 10). Figure 11 shows surface nitrates concentration along zonal sections at 30°N and 40°N in the model and in the climatology.

4.1 Section a 30 °N

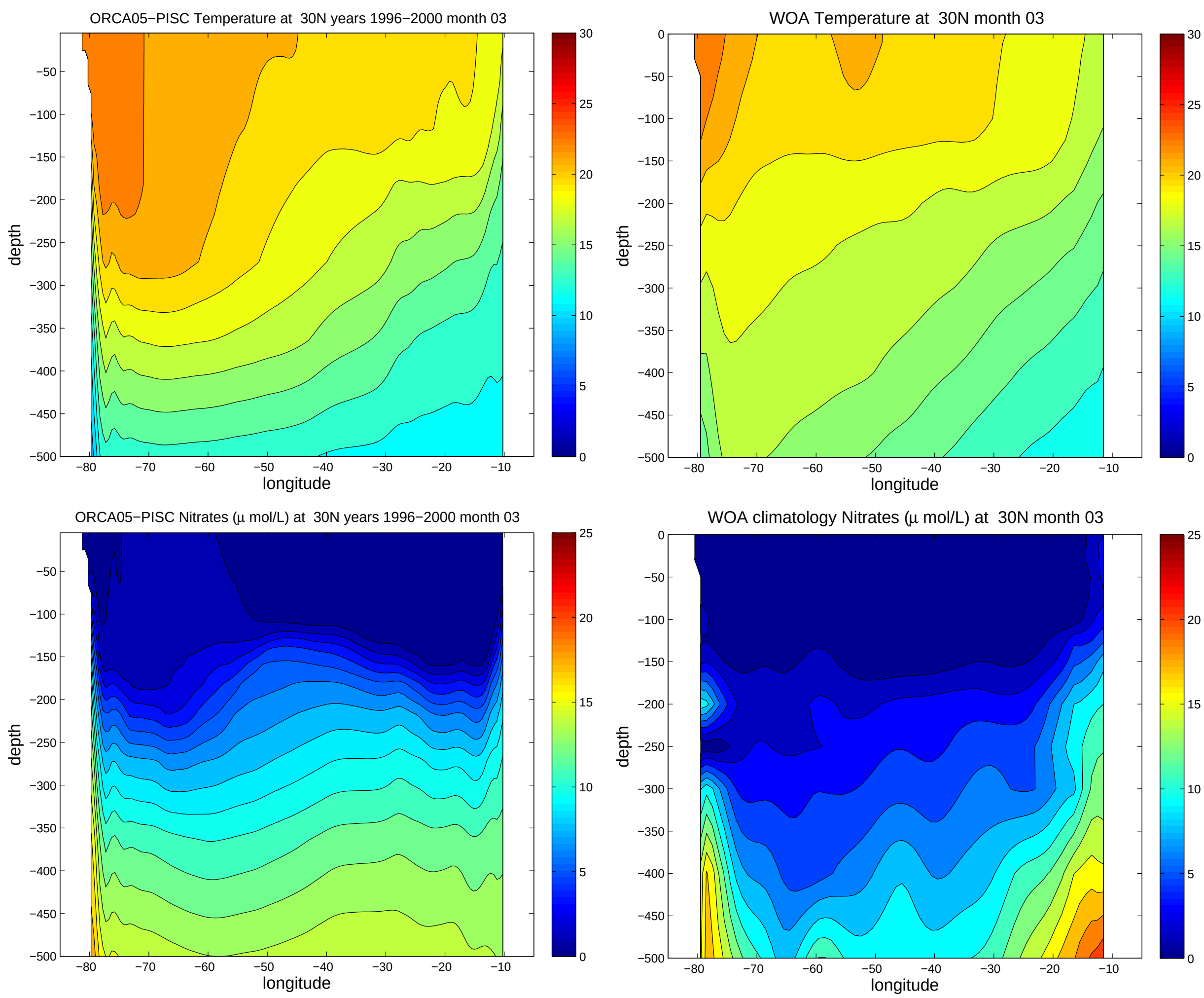

Figure 7: Temperature and Nitrates section at 30 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in march

When we look at the temperature sections at 30 °N , we notice that the extent of hot waters ($T \geq 20$ °C) overshoots by a large amount the location found in the observations and that the thermocline is higher up in the model. The isotherms are too flat which suggest a weak geostrophic flow in the subtropical gyre. The model-data differences in the nitrates sections mirror the differences in temperature: the nitracline is also too flat and shallow and the model miss the deepening in the middle of the basin. The combined discrepancies in nitrates and mixed layer depth could explain the overestimation of the primary production at 30 °N between 65°W and 50°W . The mixed layer depth in march, slightly too deep (200 m) can dig into the nitracline (which is too shallow) and thus provide an irrealistic amount of nutrients. Note that the seasonal thermocline (restratification in august, fig. 8) is rather well represented by the model, although the mixed layer depth is too shallow (Fig. 6). This may have a consequence on the surface distribution of nitrates as we will show later.

At 40 °N , there are a lot of discrepancies between the model and the observations. The nitrates concentration at depth in the middle of the basin is too high and decrease towards the east whereas the observations show a sharp decrease in the west followed by a more progressive increase. Figure 11 shows that the surface concentration in spring is much larger in the model except in the east or in some small areas and became negligible in august.

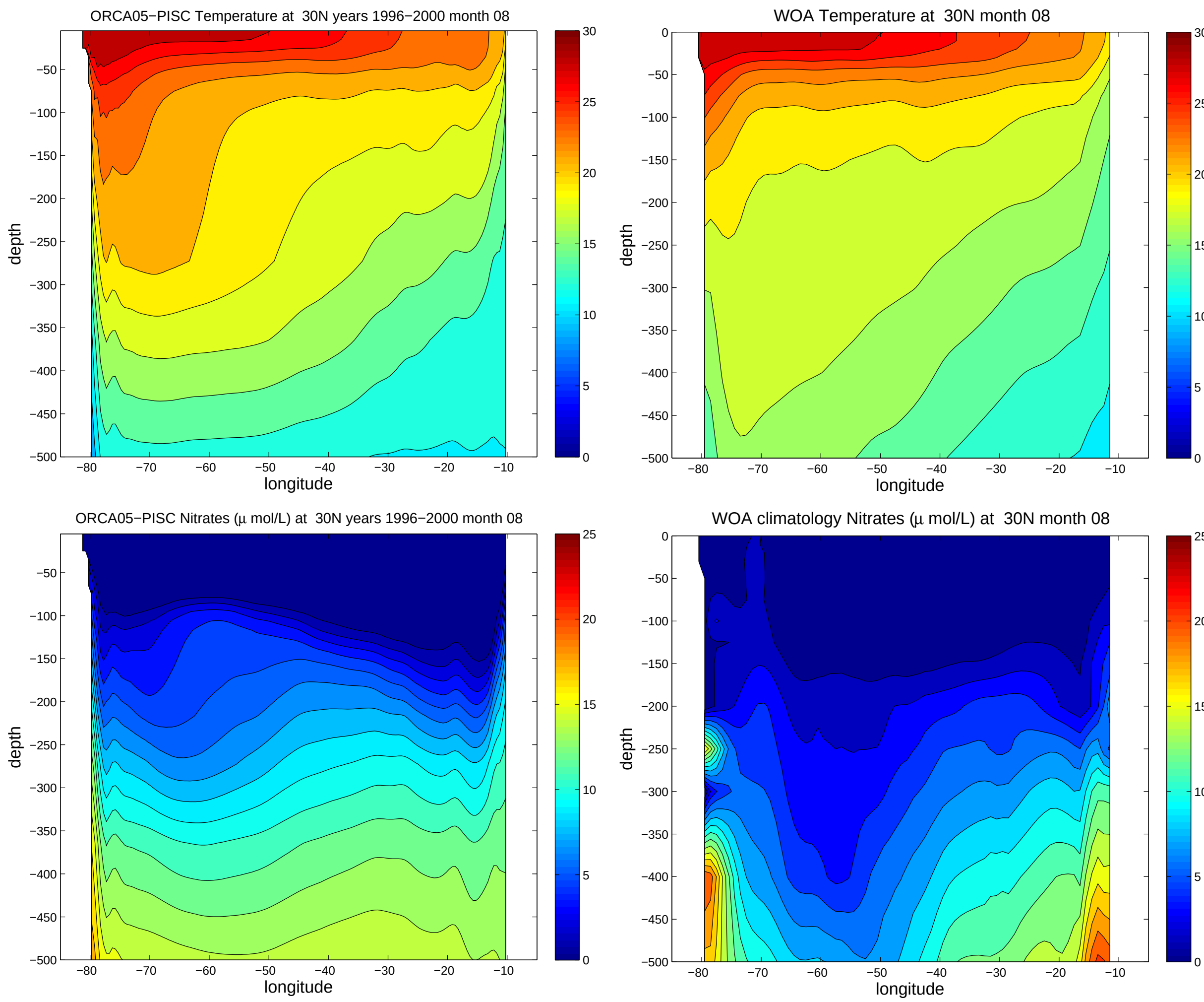

Figure 8: Nitrates section at 30 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in august

4.2 Section a 40 °N

At 40 °N , the model's thermocline structure is also very unrealistic (fig. 9). Again, the thermocline is too flat. The most notable feature is the absence of the sharp gradient near the western boundary, which shows that the strength of the geostrophic shear in the western boundary current is largely underestimated. This is to be expected. The observed transport of the Gulf Stream is about 100 Sv, most of which occurs in the upper layers. The linear Sverdrup circulation is only about 20-30Sv. ORCA05 has no eddies and no inertial recirculation, therefore it represents only the Sverdrup dynamics and cannot reproduce the total baroclinic transport of the Gulf Stream.

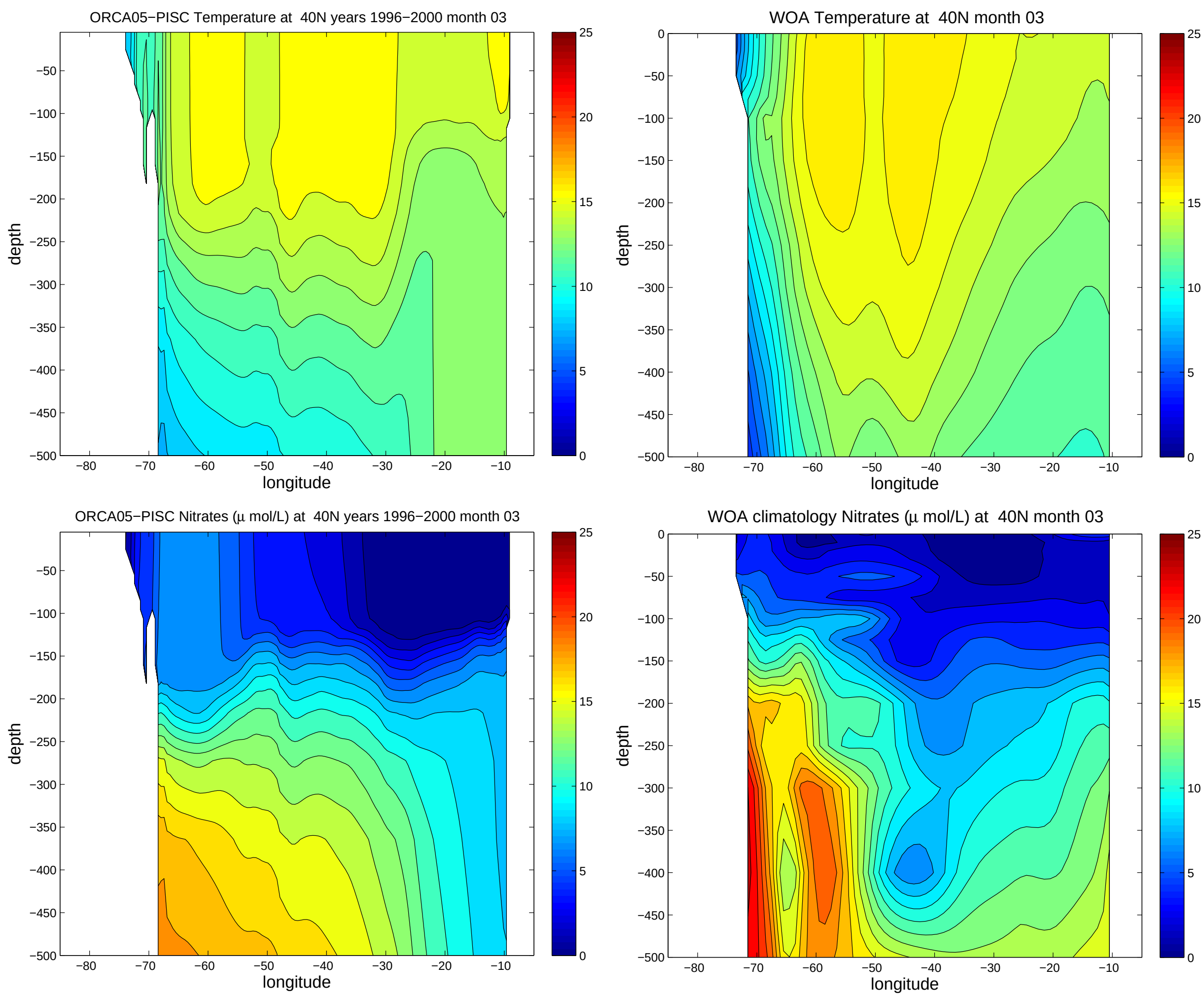

Figure 9: Temperature and Nitrates section at 40 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in march

Moreover, ORCA05 does not represent the cold slope waters advected north of the Gulf Stream from the Labrador shelf. Next to the western boundary, instead of the region of strong gradient between the slope waters and the subtropical waters, the model has no cold water, very weak gradients and a region of vertically homogeneous temperature and nitrates extending down to 200m. Anomalously high levels of nitrates are found near the surface all the way to 40W (fig. 9). This, combined with larger than observed winter mixed layers, is clearly the explanation for the anomalously high primary production west of 40W in the model at 40N. In the eastern part of the section, the model shows a spurious patch of homogeneous waters under 150 meters. This is certainly due to a bad representation of the Mediterranean water overflow, which is too shallow (centered at 400m instead of 800-1000m as observed along the section, see fig 13.

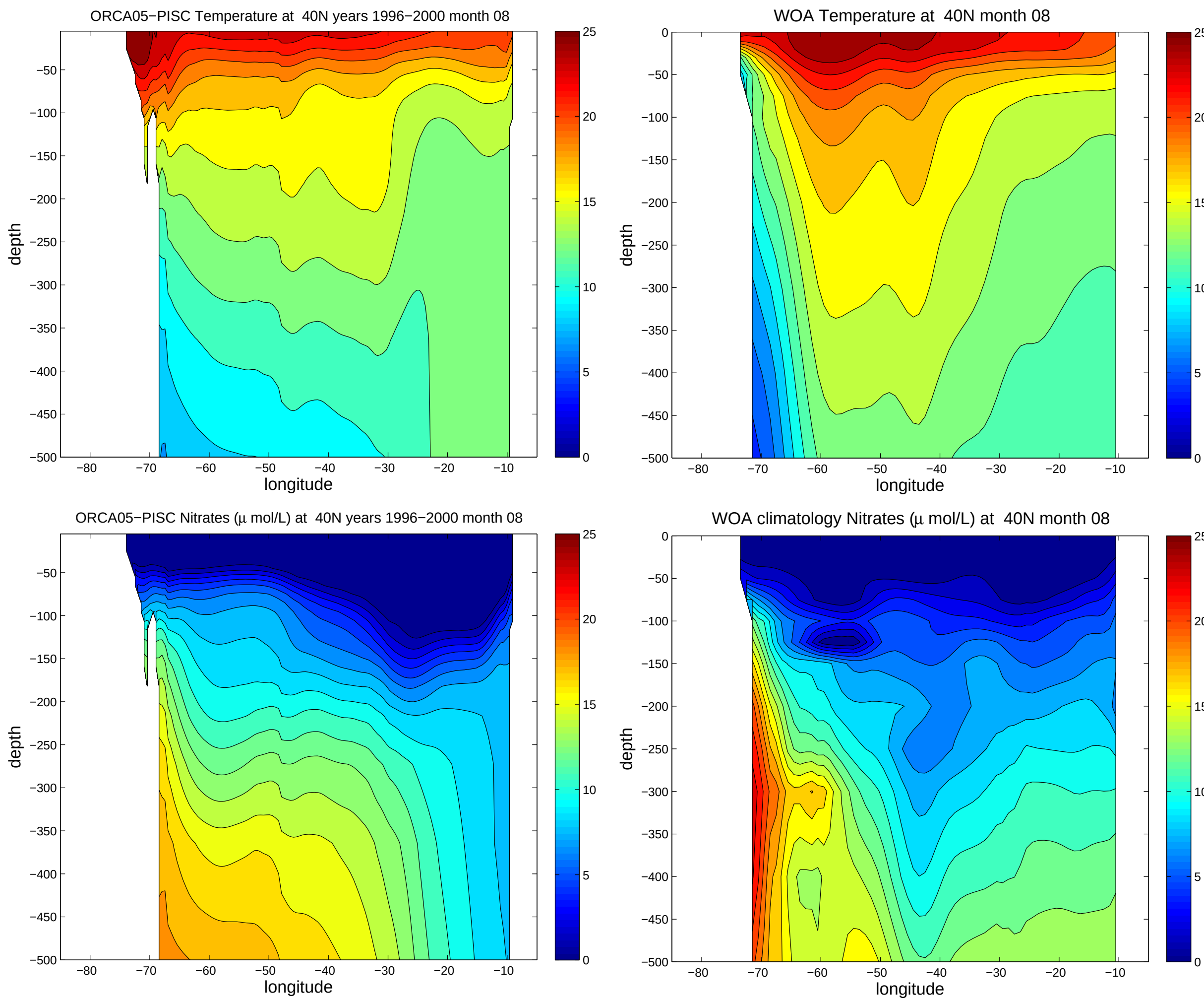

Figure 10: Nitrates section at 40 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in august

Figure 11 shows surface nitrates concentration along zonal sections at 30°N and 40°N in the model and in the climatology. The model considerably underestimates the nitrates in August (why is that? could there be a bug in Levitus? the nitrates are supposed to be exhausted in summer in the mixed layer, are they not??). Could the discrepancy come from the fact that the model mixed layers are too shallow in August?

There are no nitrates at the surface in the model east of 25W, all year round. Why does the model miss completely the source of nitrates in the eastern Atlantic? Is it because of the wrong representation of the thermocline? Or the lack of upwelling along the portuguese coast?

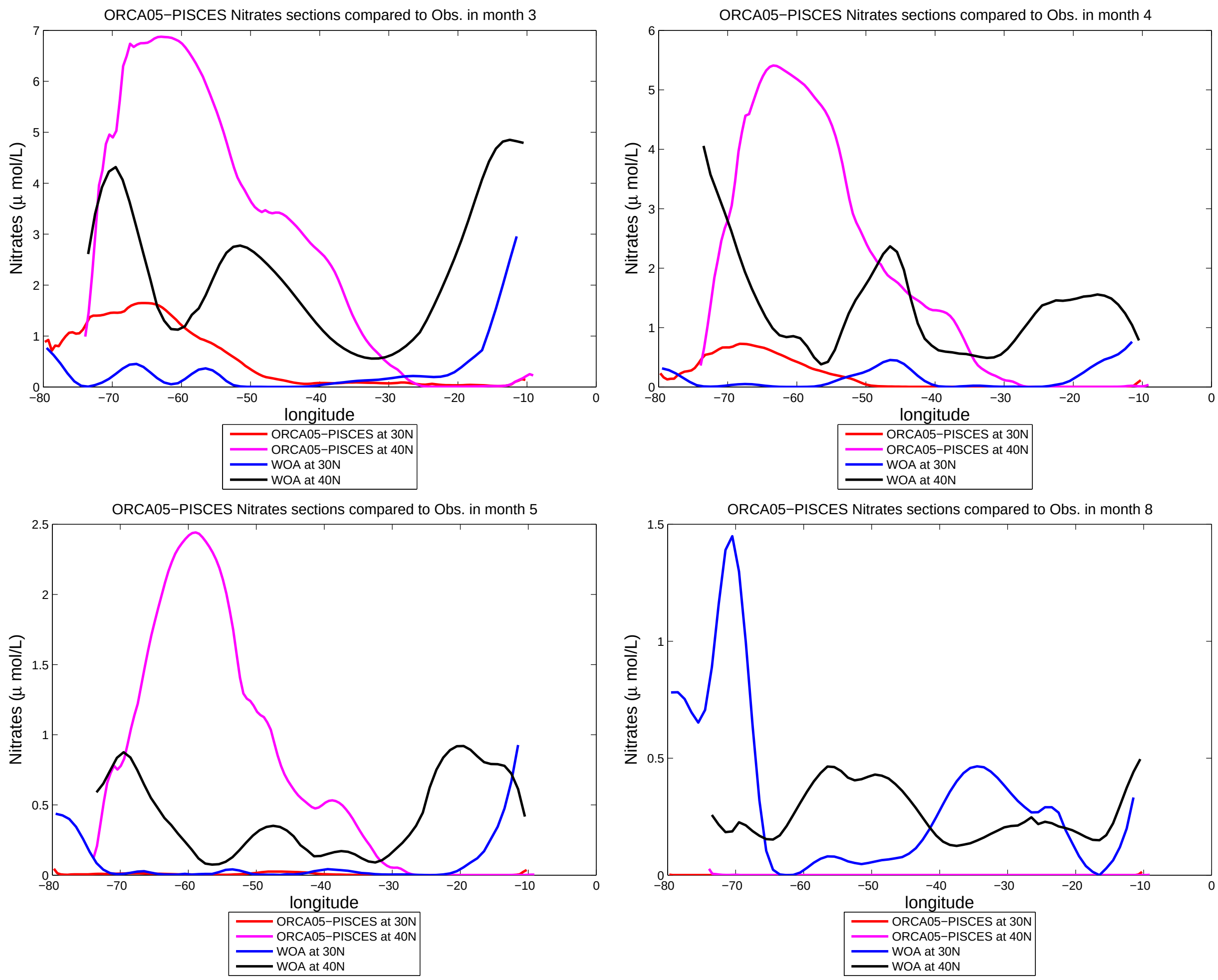

Figure 11: Nitrates sections in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in march, april, may and august

5 Comparaison with ORCA05-G70.114

The weakness of the subtropical gyre in ORCA05-PISCINT3 seems to play a part in the bad representation of primary production. In this section, we compare temperature, density and mixed layer depth from ORCA05-PISCINT3 with a DRAKKAR run at the same resolution (namely ORCA05-G70.114) and the World Ocean Atlas. We are not sure about the differences between the two simulations settings, because we don't have all the parameters for the ORCA05-PISCINT3. It seems that a Gent-McWilliams (GM) parameterization is used in ORCA05-PISCINT3 but not in ORCA05-G70.114. The figures show the sections down to 1500 m to better show the bowl-shape structure of the subtropical thermocline. Figures 12 and 13 show a comparison of temperature along section at 30°N and 40°N in march and august, figures 14 and 15 show a comparison of the potential density σ_0 along the same sections and for same months. Finally, figure 16 is a comparison of mixed layer depth between ORCA05-PISCINT3 and ORCA05-G70.114 in march, april, may and august.

Firstly, we look at the temperature sections (cf fig. 12 & 13). At 30°N , we notice that the temperature in ORCA05-G70 is overally colder than in ORCA05-PISCINT3 which is in better agreement with the World Ocean Atlas. We also have a lower and thicher thermocline which is also an improvement. The flatter "bowl" shape in ORCA05-PISCINT3 could be due the use of the GM parameterization. Furthermore, the mediterranean outflow seems better in ORCA05-G70 because the homogeneous waters at the eastern boundary are better positioned on the vertical. At 40°N (Fig. 13), ORCA05-G70.114 shows a litte improvement in the eastern part of the section but there are very irregular isotherms and the thermocline is too high in the water column. The noisier profiles in the DRAKKAR run could be due to the absence of the GM parameterization.

The same features appear in the density section (cf fig. 14 & 15). At 30°N , density in ORCA05-PISCINT3 and ORCA05-G70.114 is very similar but the latter shows a tiny improvement on the slope of isopycnes. At 40°N , we have an improvement at subsurface but the depth and the thickness of the pycnocline are very similar. In conclusion, the DRAKKAR run ORCA05-G70.114 represents only a small improvement over ORCA05-PISCINT3, and it is quite likely that running pisces with the DRAKKAR version of ORCA05 would not improve considerably the biogeochemistry.

5.1 Temperature section at 30 °N

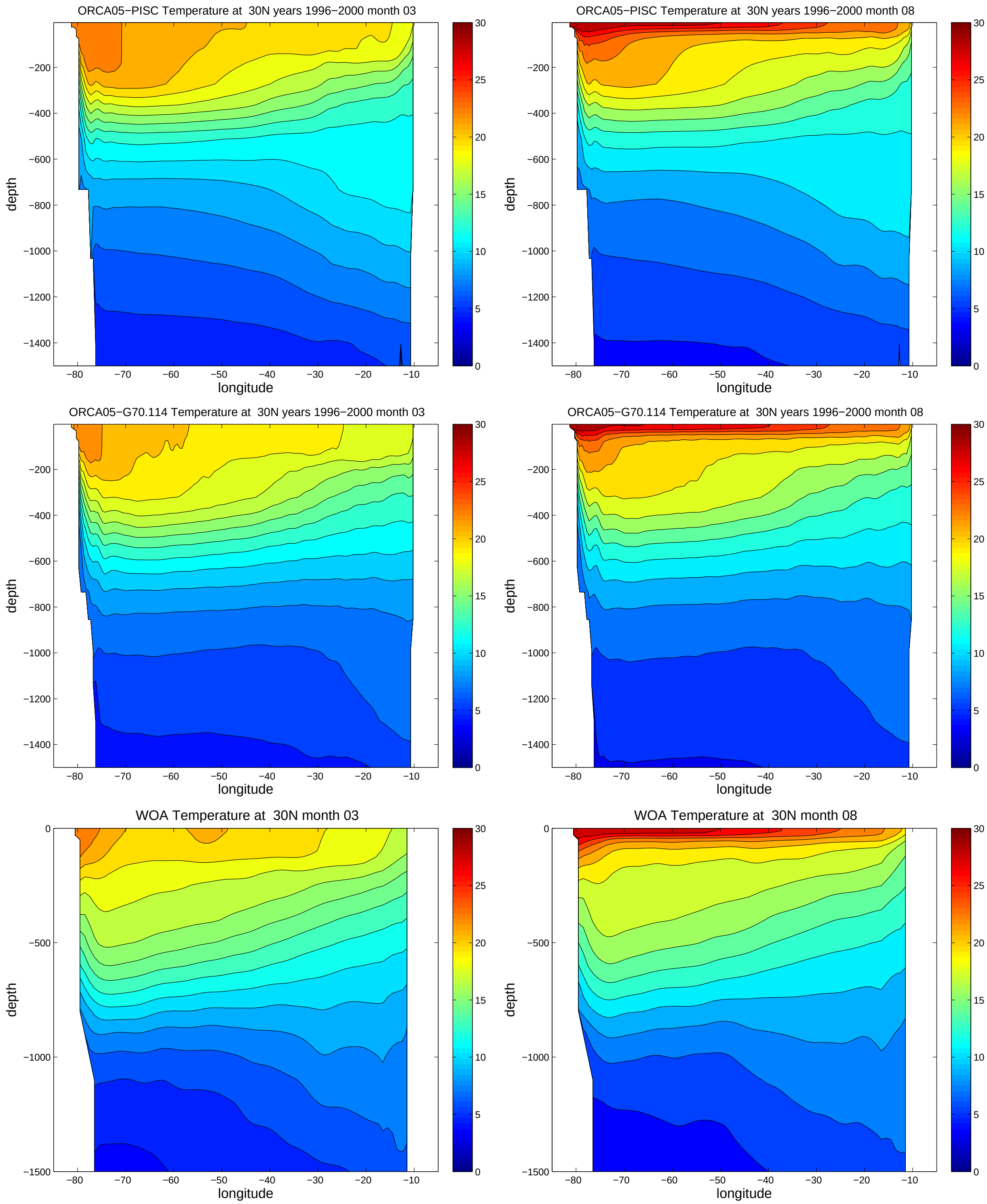

Figure 12: Temperature section at 30 °N in ORCA05-PISCES years 1996-2000 compared with ORCA05-G70.114 and World Ocean Atlas in march and august

5.2 Temperature section at 40 °N

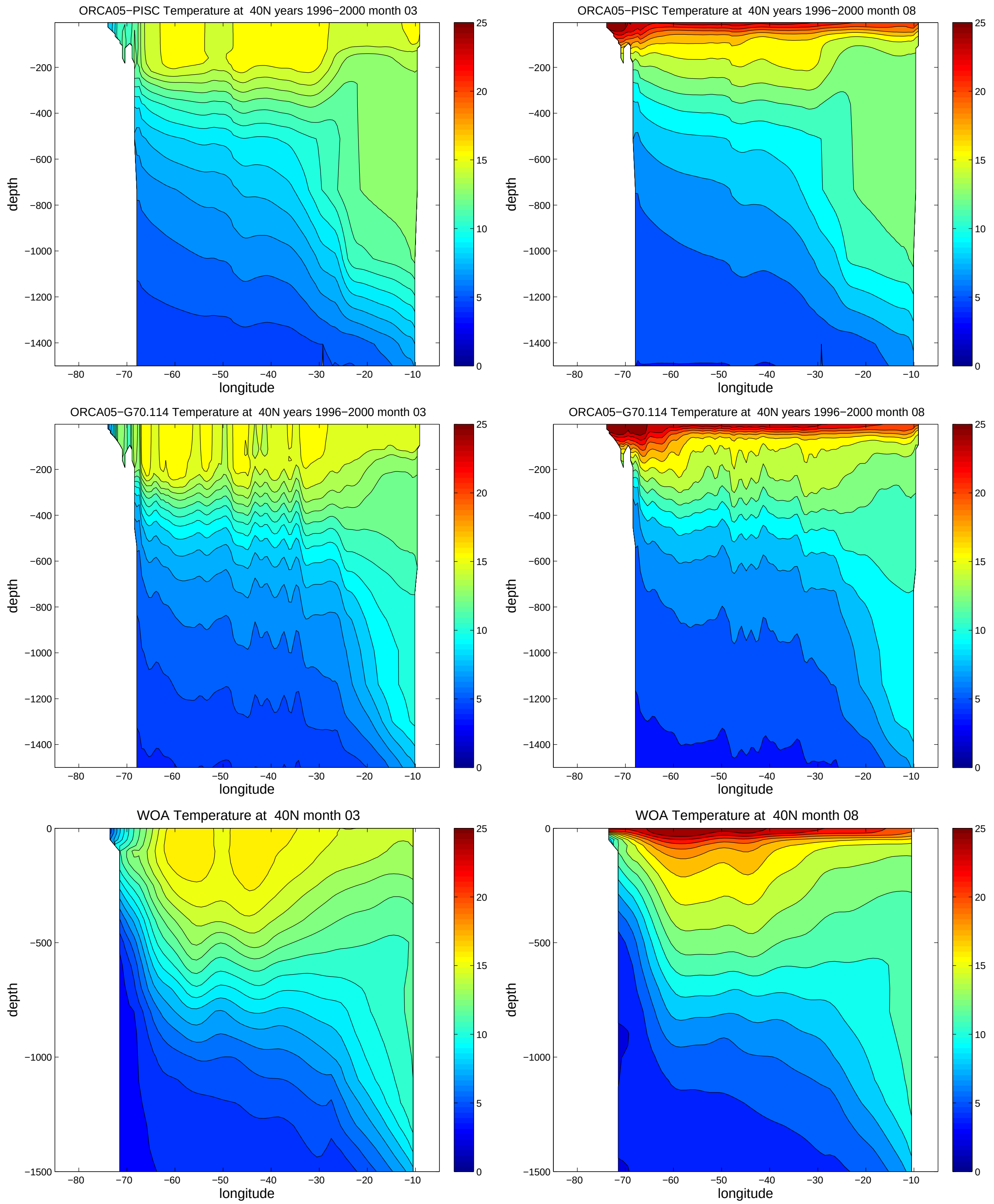

Figure 13: Temperature section at 40 °N in ORCA05-PISCES years 1996-2000 compared with ORCA05-G70.114 and World Ocean Atlas in march and august

5.3 Density section at 30 °N

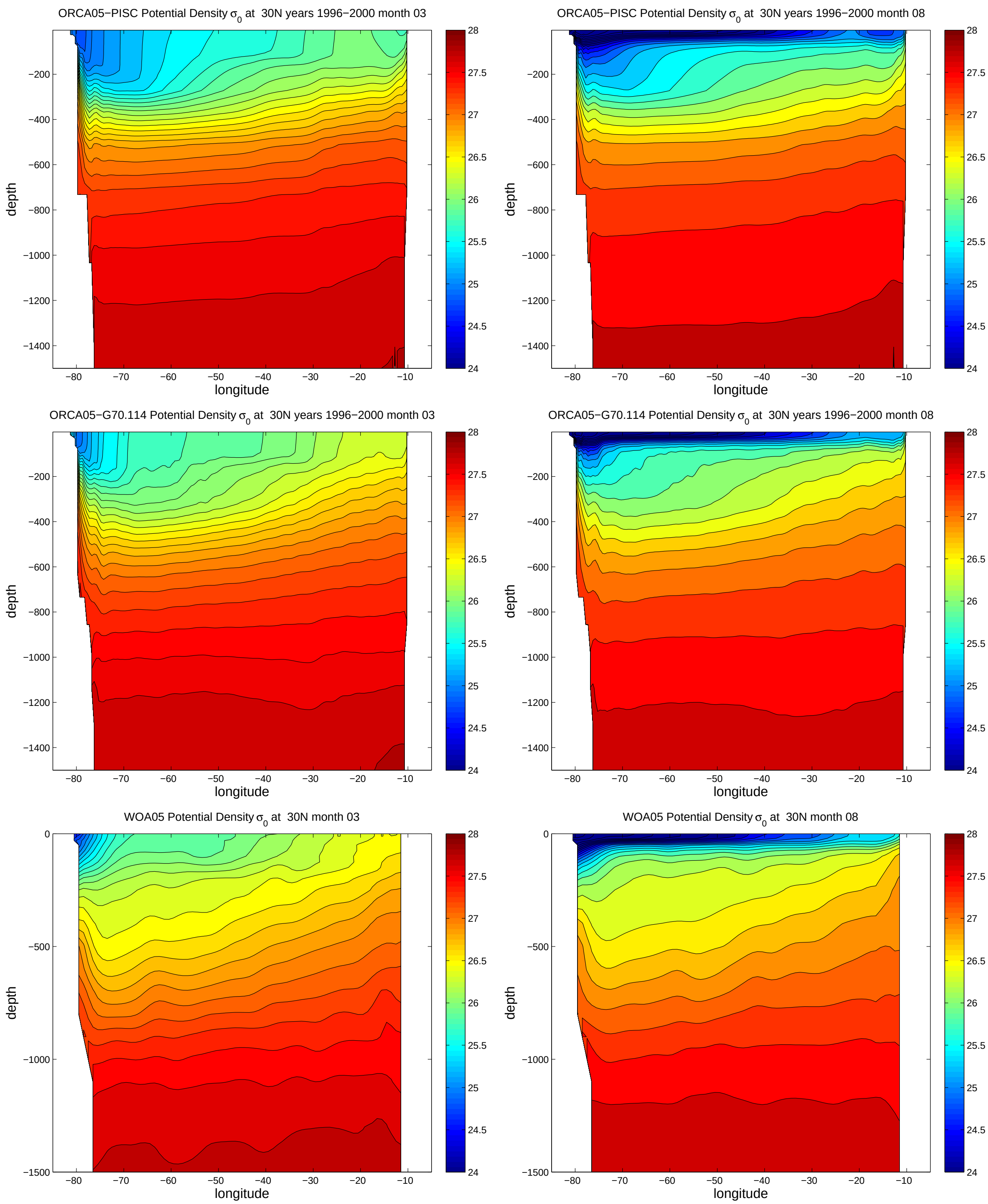

Figure 14: Density section at 30 °N in ORCA05-PISCES years 1996-2000 compared with ORCA05-G70.114 and World Ocean Atlas in march and august

5.4 Density section at 40 °N

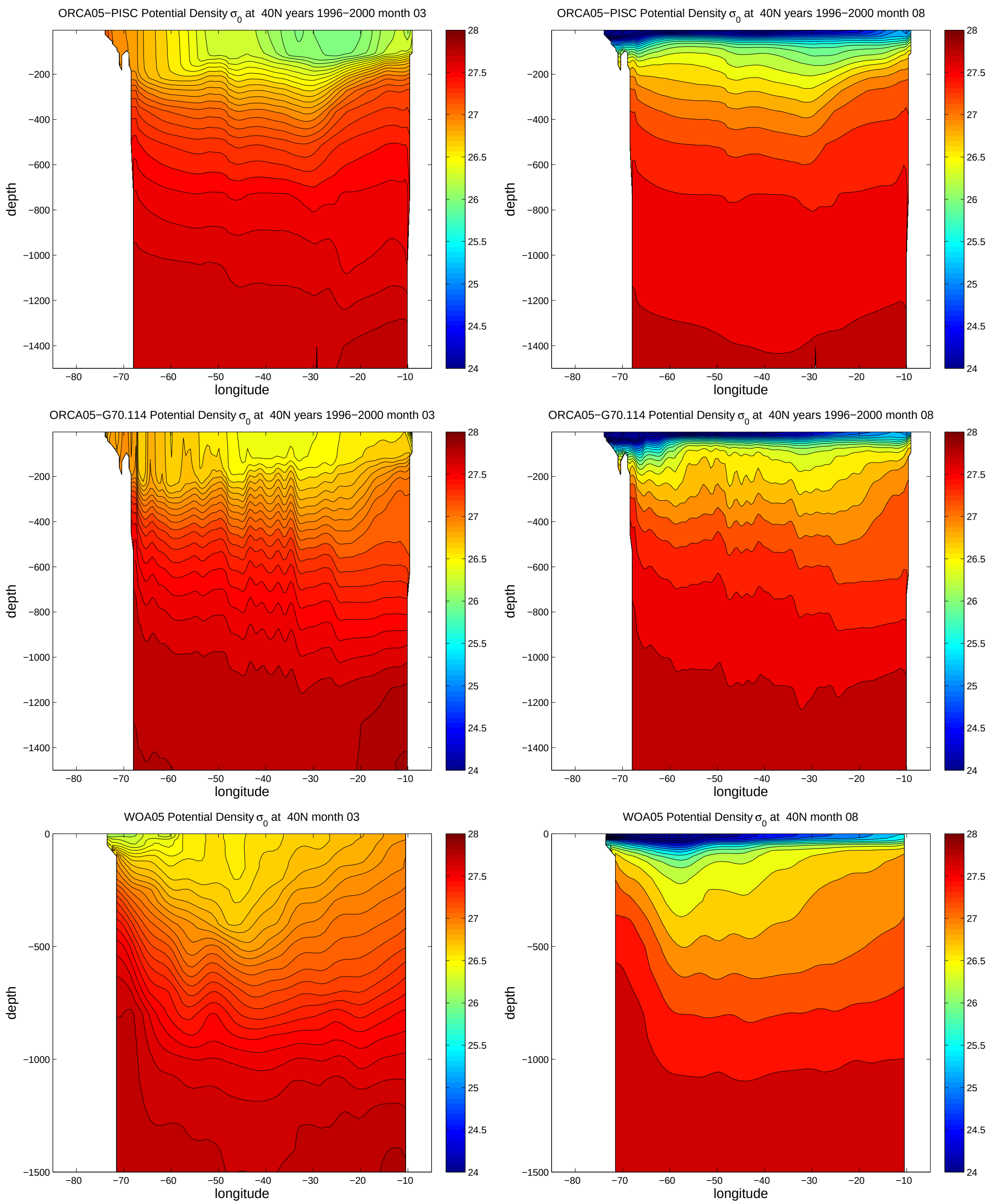

Figure 15: Density section at 40 °N in ORCA05-PISCES years 1996-2000 compared with ORCA05-G70.114 and World Ocean Atlas in march and august

5.5 Mixed layer depth sections at 30 and 40°N

At 30°N , ORCA05-G70.114 has a shallower mixed layer in the western part of the section in spring which is an improvement compared to ORCA05-PISCINT3. In the remaining part of the section, the mixed layer of ORCA05-G70.114 is comparable to ORCA05-PISCINT3 but the former is slightly shallower especially in the eastern part. At 40°N , we notice that the mixed layer of ORCA05-G70.114 is deeper in april and may between 70°W and 50°W , slightly deeper in the east in spring but globally very comparable with ORCA05-PISCINT3.

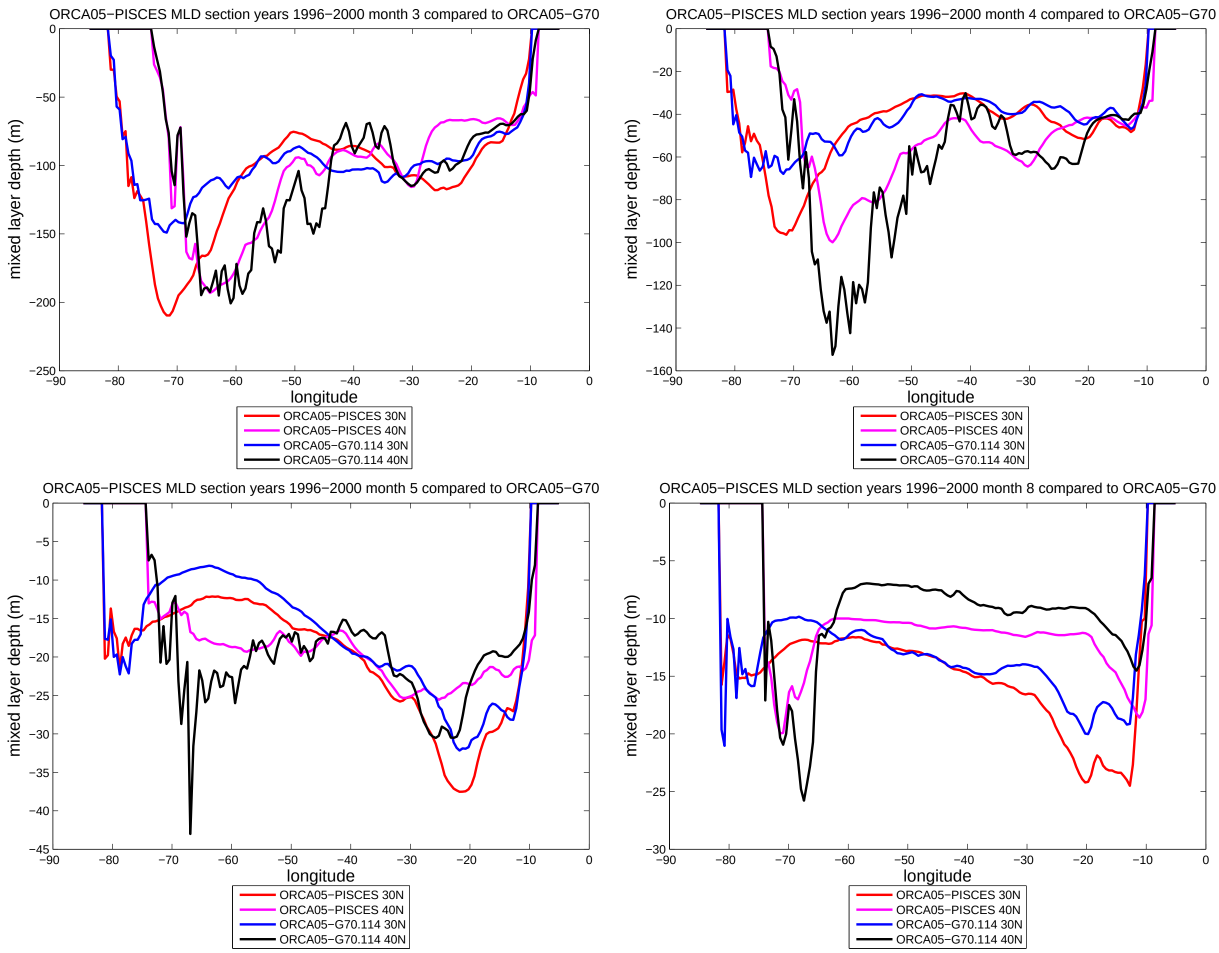

Figure 16: Mixed Layer Depth in ORCA05-PISCES years 1996-2000 compared with ORCA05-G70.114 in march, april, may and august

6 Results from ORCA025-G70 and NATL12-BAMT20

Let us now compare the ORCA05 results with DRAKKAR simulations at higher resolution. We use ORCA025-G70, a 1/4 degree global run (Molines et al, 2006) and NATL12-BAMT20, a north Atlantic 1/12 simulation (Treguier 2008).

The shape of the pycnocline and the representation of Mode waters seem to improve with resolution. NATL12 provides the best solution.

6.1 Temperature section at 30 °N

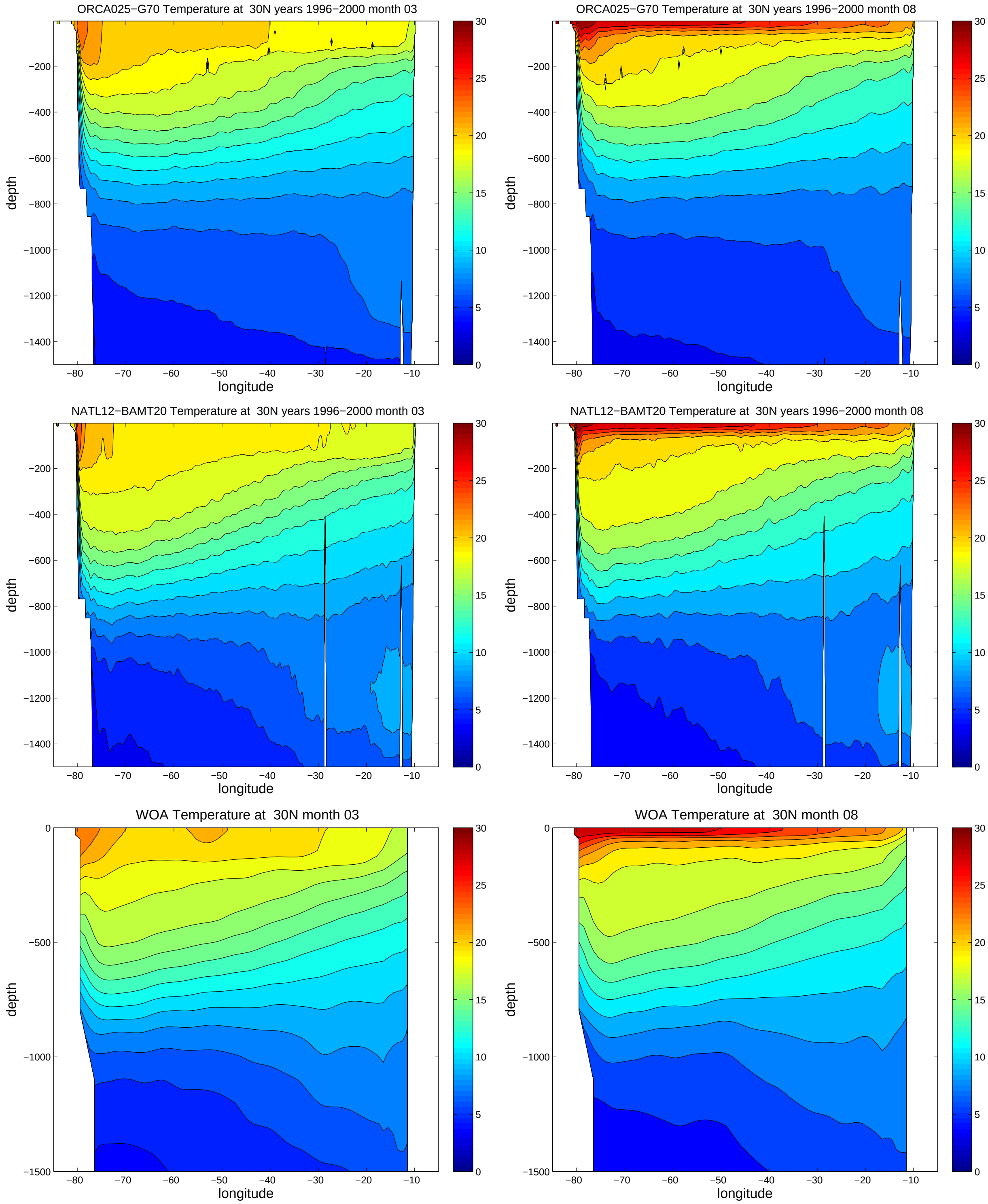

Figure 17: Temperature section at 30 °N in ORCA025-G70, NATL12-BAMT20 years 1996-2000 compared with World Ocean Atlas in march and august

6.2 Temperature section at 40 °N

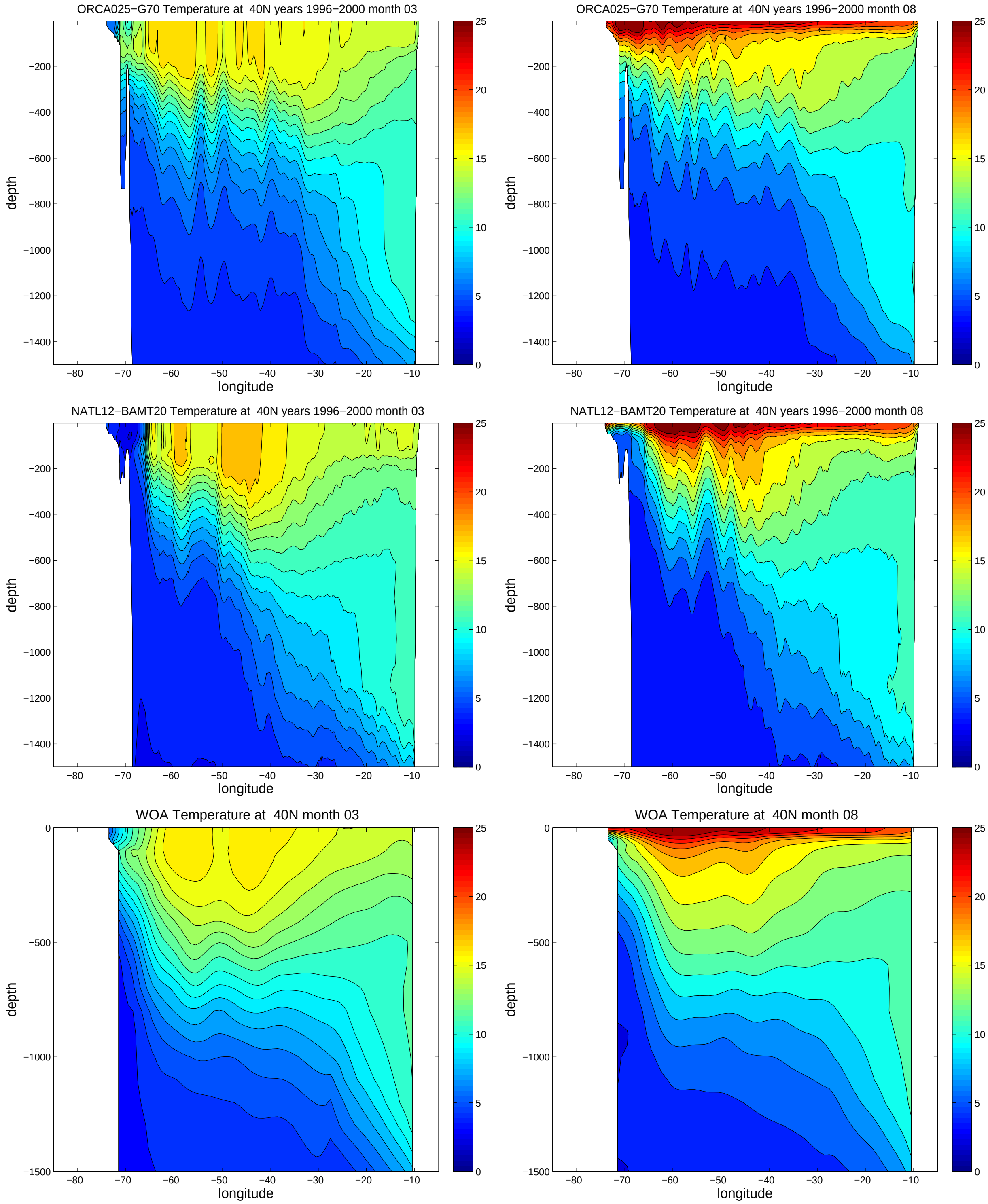

Figure 18: Temperature section at 40 °N in ORCA025-G70, NATL12-BAMT20 years 1996-2000 compared with World Ocean Atlas in march and august

6.3 Density section at 30 °N

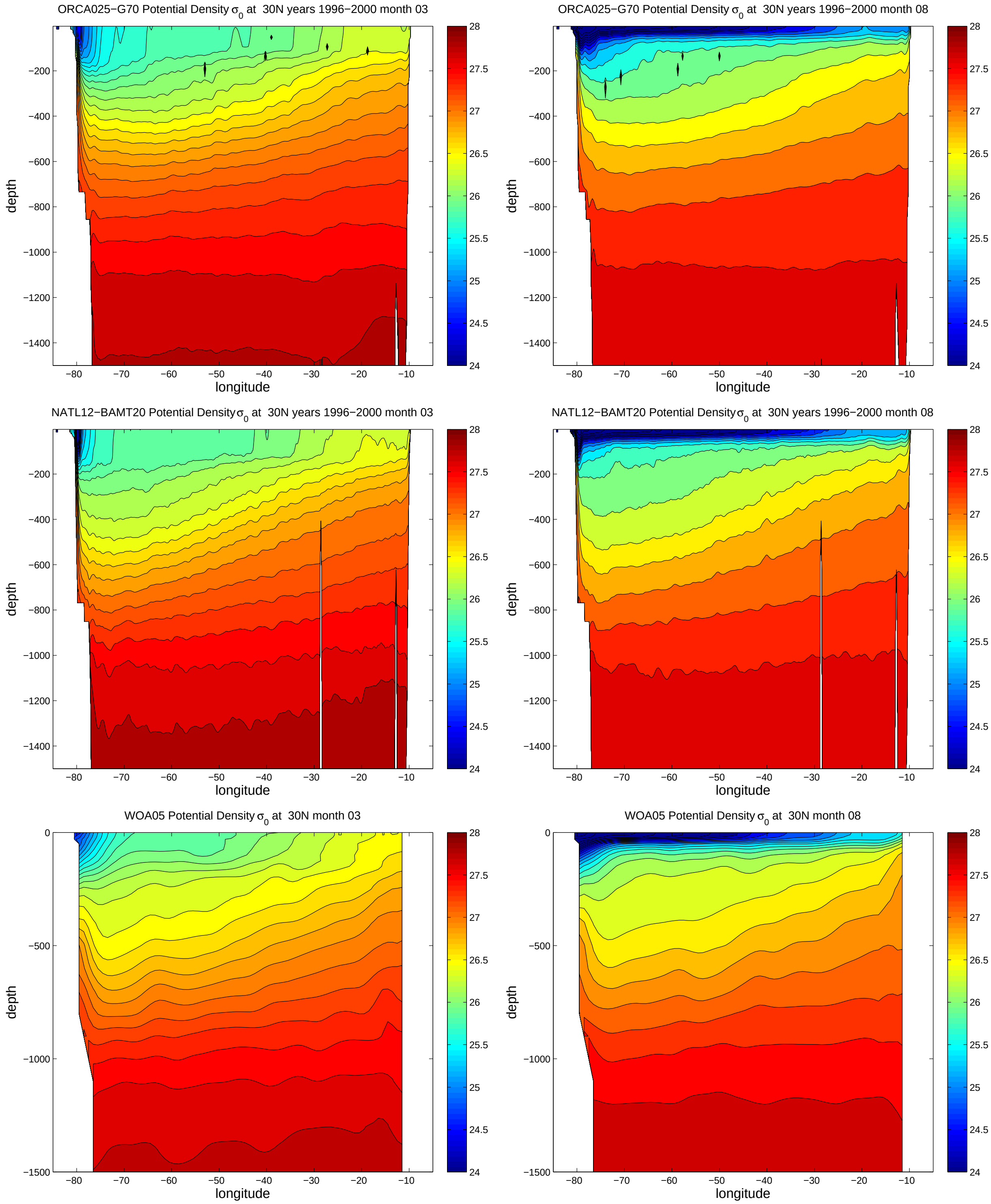

Figure 19: Density section at 30 °N in ORCA025-G70, NATL12-BAMT20 years 1996-2000 compared with World Ocean Atlas in march and august

6.4 Density section at 40 °N

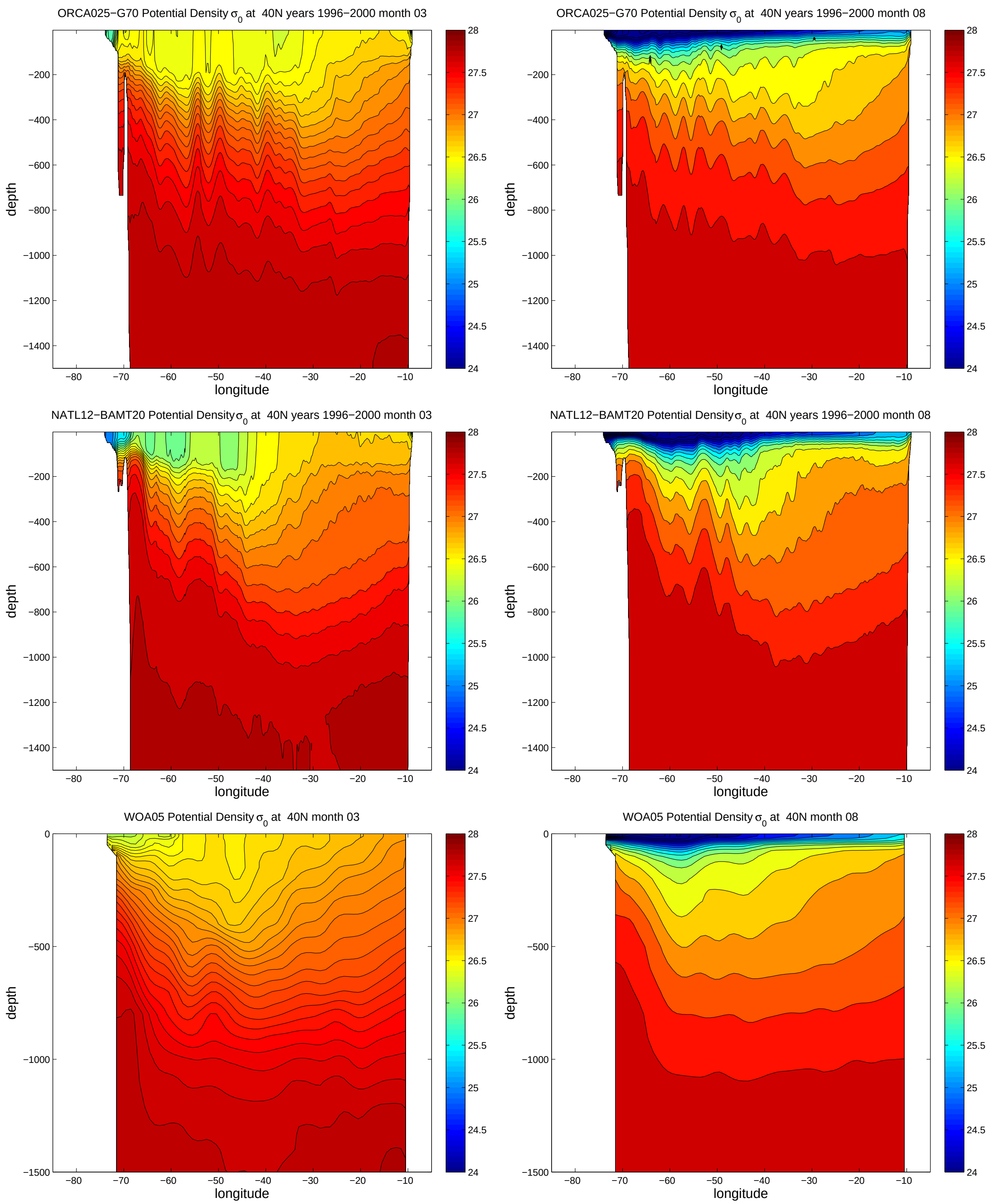

Figure 20: Density section at 40 °N in ORCA025-G70, NATL12-BAMT20 years 1996-2000 compared with World Ocean Atlas in march and august

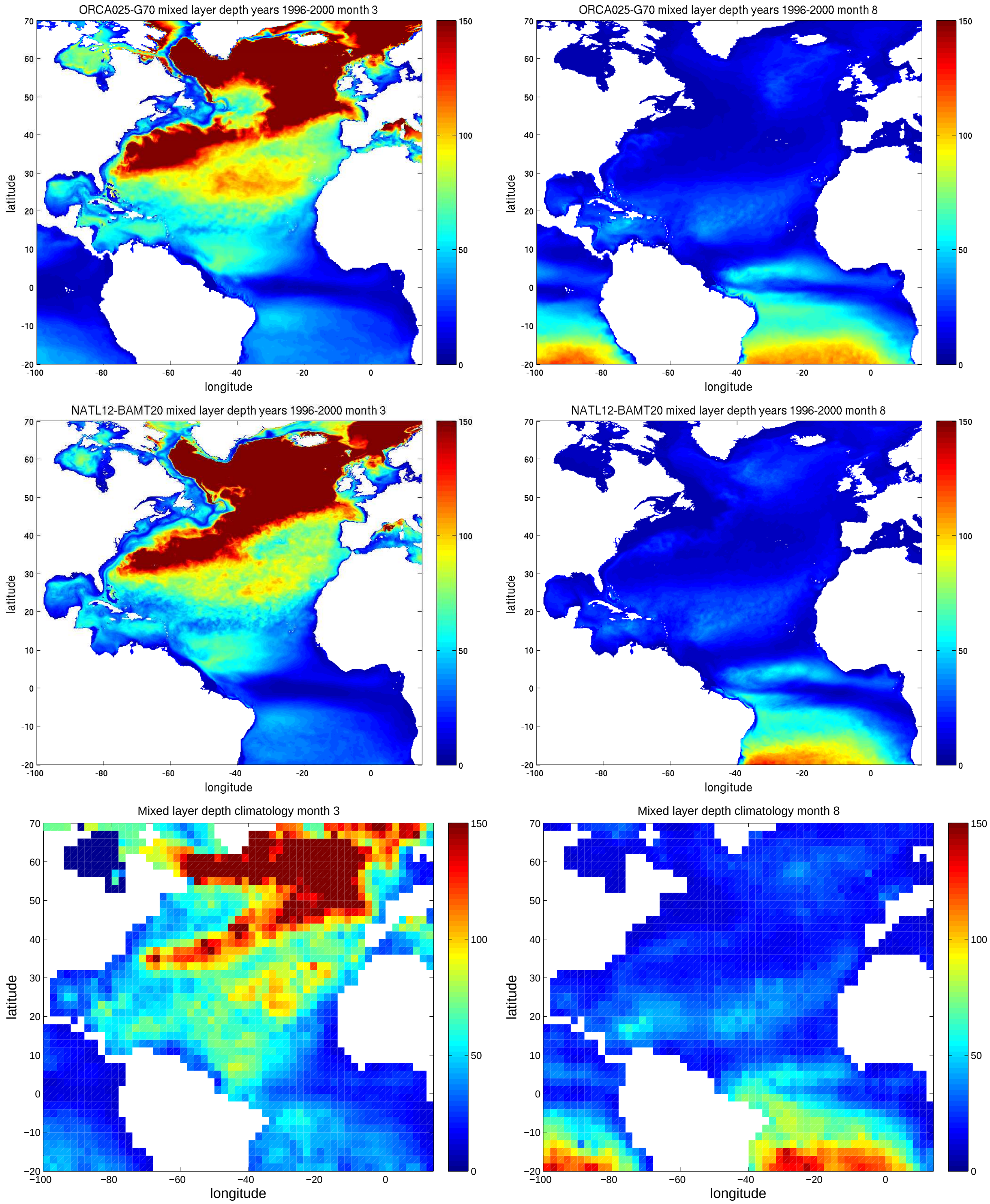

Figure 21: Mixed layer depth in ORCA025-G70, NATL12-BAMT20 years 1996-2000 compared with Climatology in march and august

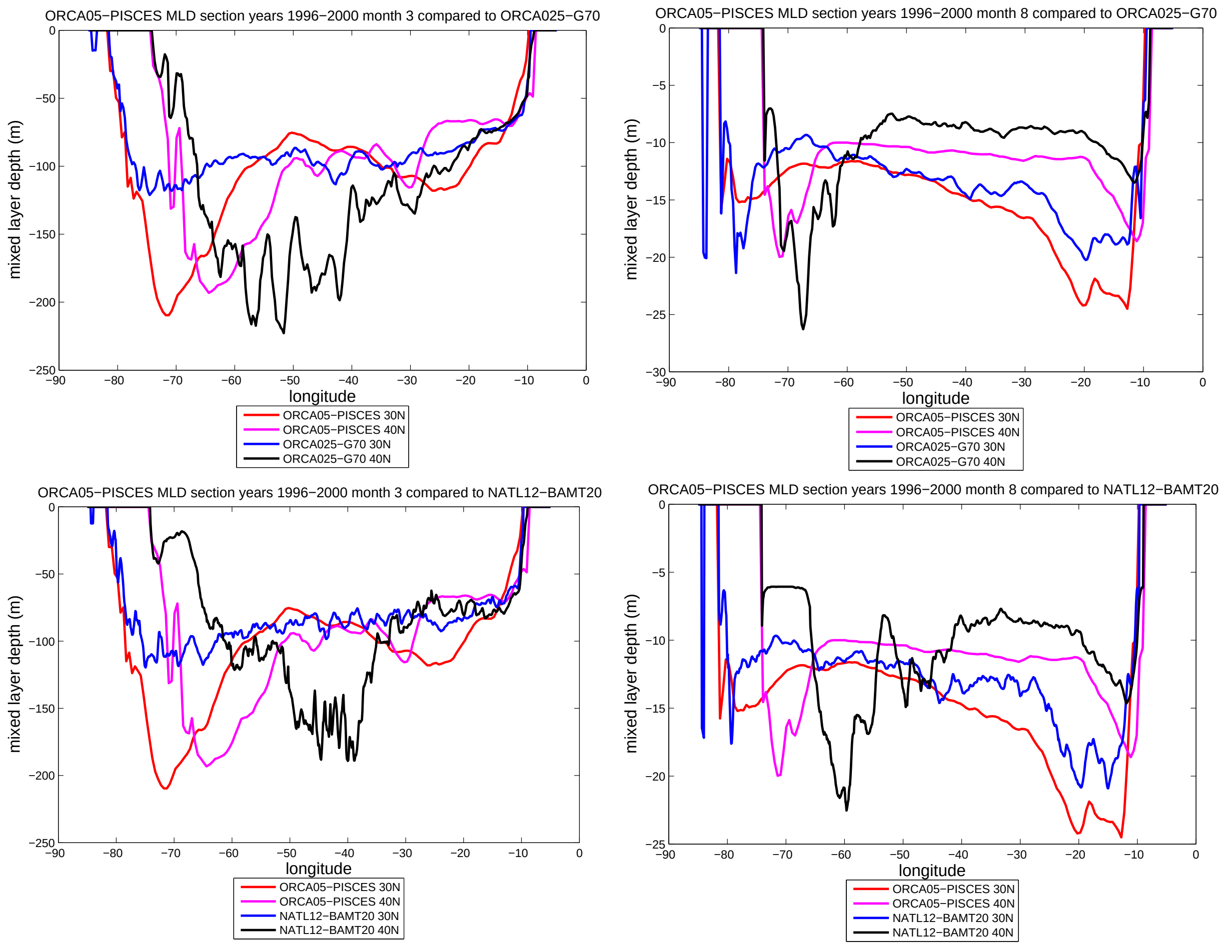

Figure 22: Mixed Layer Depth in ORCA05-PISCES years 1996-2000 compared with ORCA025-G70 and NATL12-BAMT20 in march and august

Appendices

Annex 1 : results from Mercator ORCA025 offline experiment

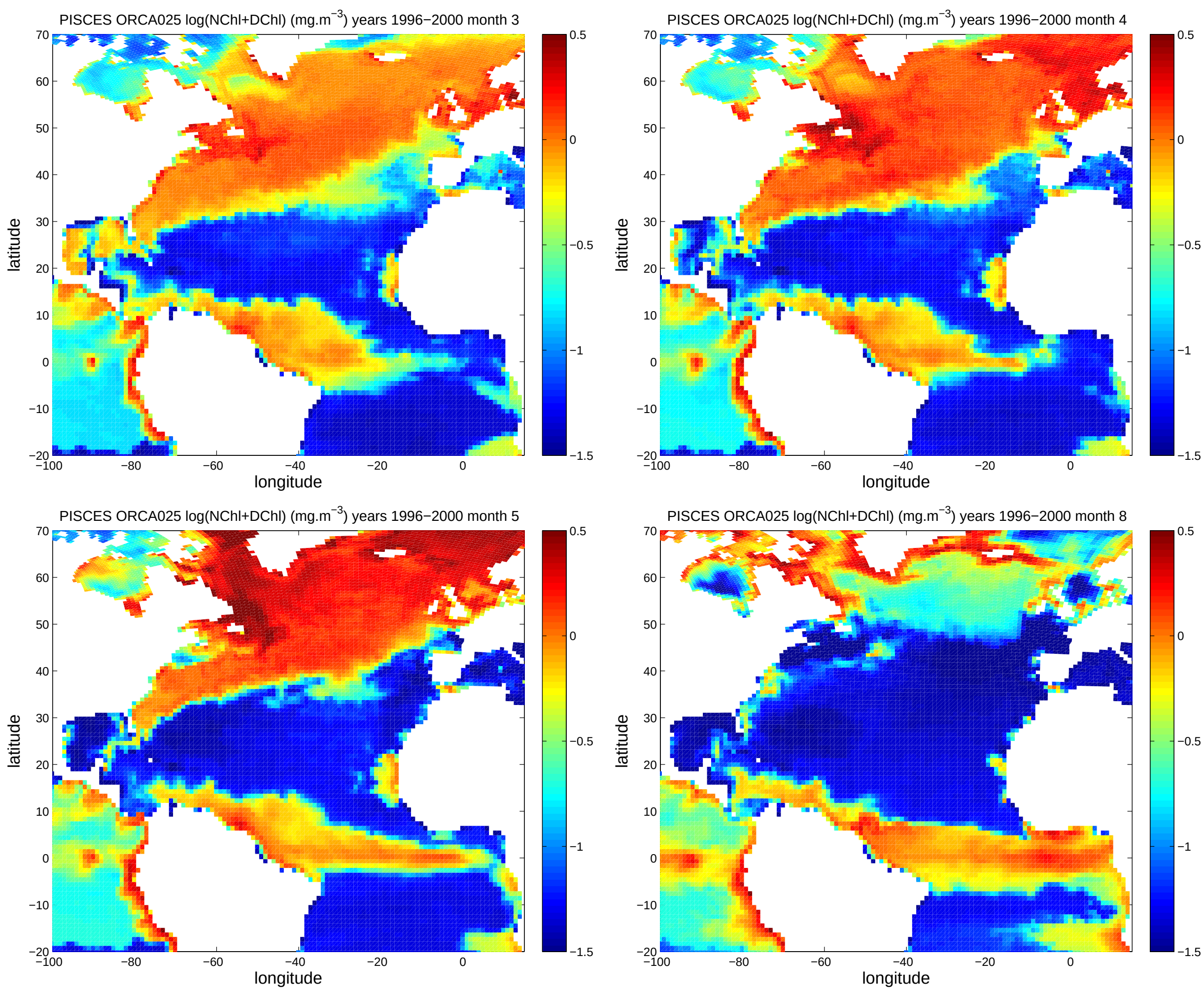

Figure 23: Mean surface chlorophyll in PISCES-ORCA025-BIO1-DMP3 year 2002 march, april, may and august

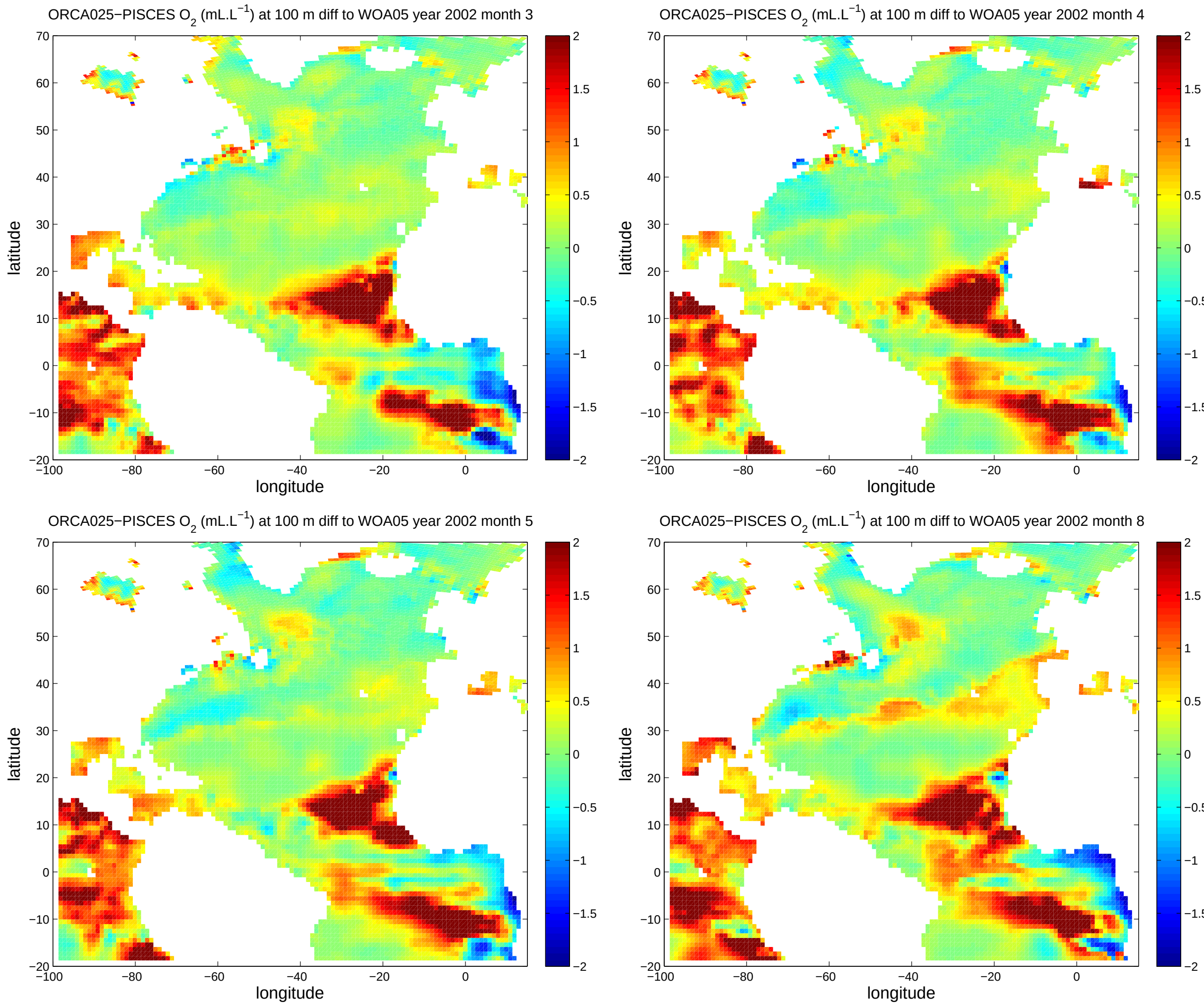

Figure 24: Mean oxygen at 100m in ORCA025-PISCES year 2002 diff to WOA05 in march, april, may and august

Annex 2 : Comparaison of Temperature and Salinity with World Ocean Atlas

We compute the difference between the model and the World Ocean Atlas 2005 climatology. Looking at the temperature maps, we see that the model is too hot in most of the coastal regions (along Africa, North and South America) and in the tropics. It is also too cold in the Labrador Sea and below. The salinity maps shows has a minimum of salinity in the middle of the Atlantic at 45 °N and an excess of salinity in the vicinity of major rivers.

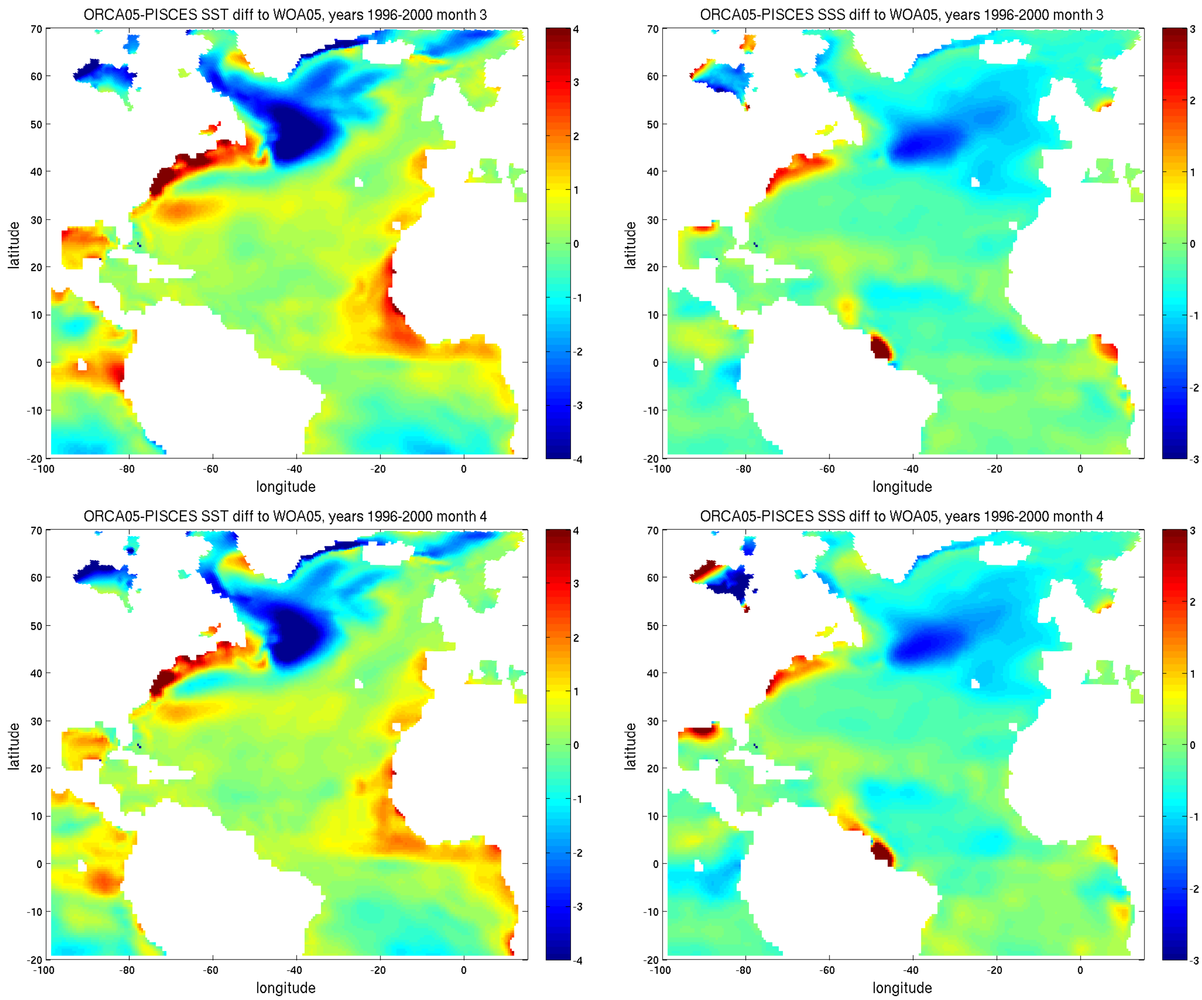

Figure 25: SST & SSS : ORCA05-PISCES diff to WOA05, years 1996-2000 in march and april

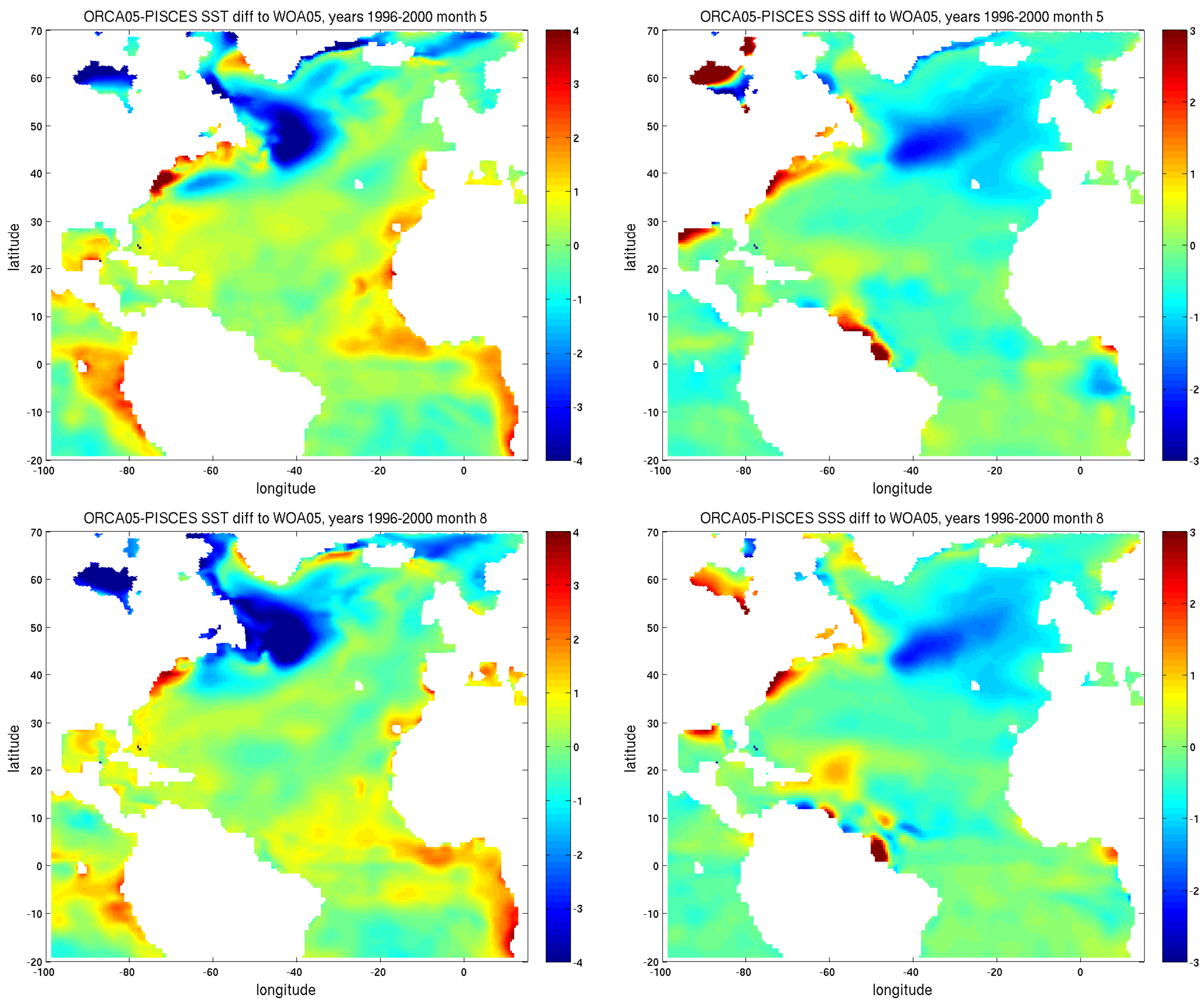

Figure 26: SST & SSS : ORCA05-PISCES diff to WOA05, years 1996-2000 in may and august

Annex 3 : Comparaison of oxygen with World Ocean Atlas

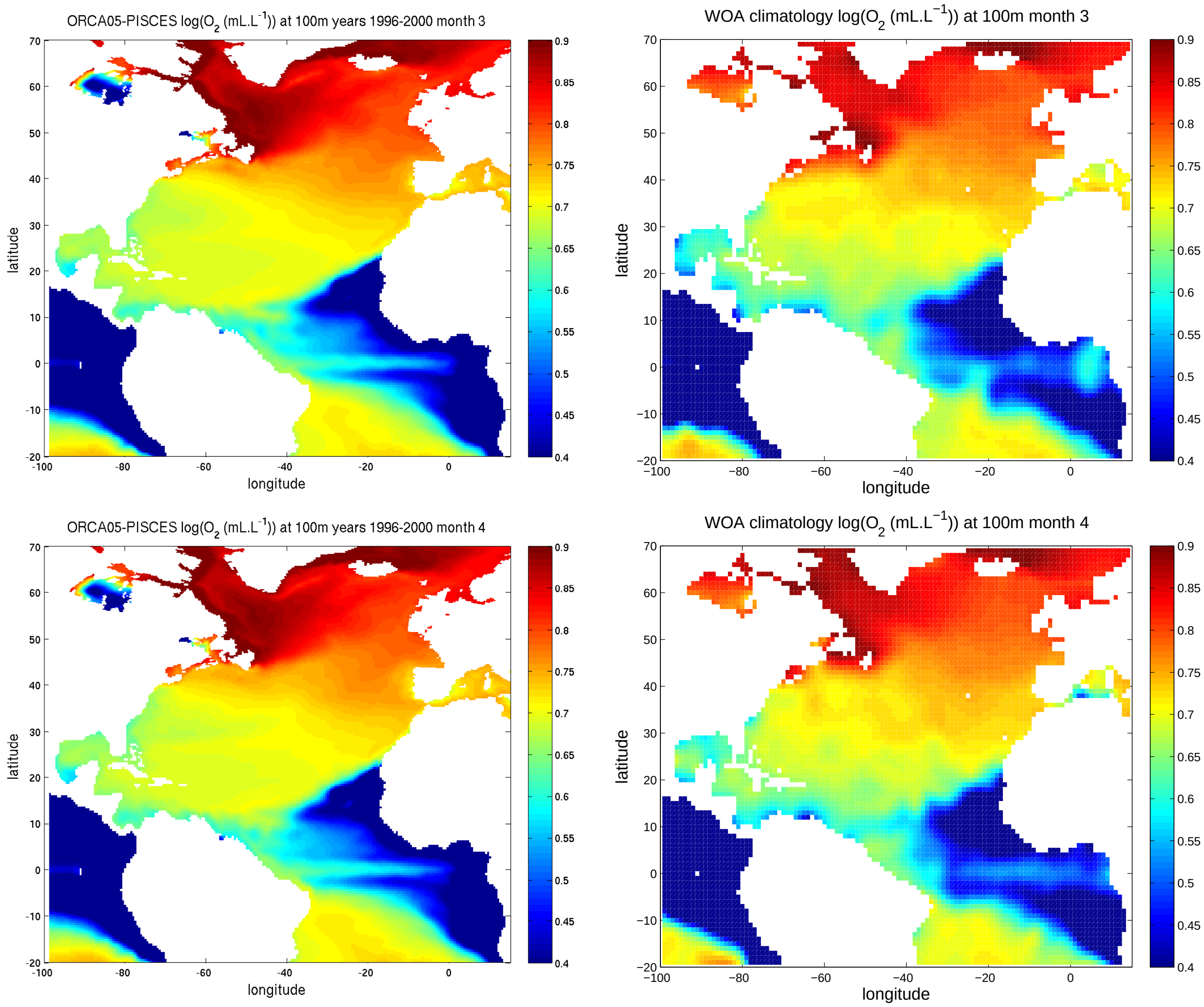

Figure 27: Oxygen at 100m in ORCA05-PISCES years 1996-2000 and WOA05 in march and april

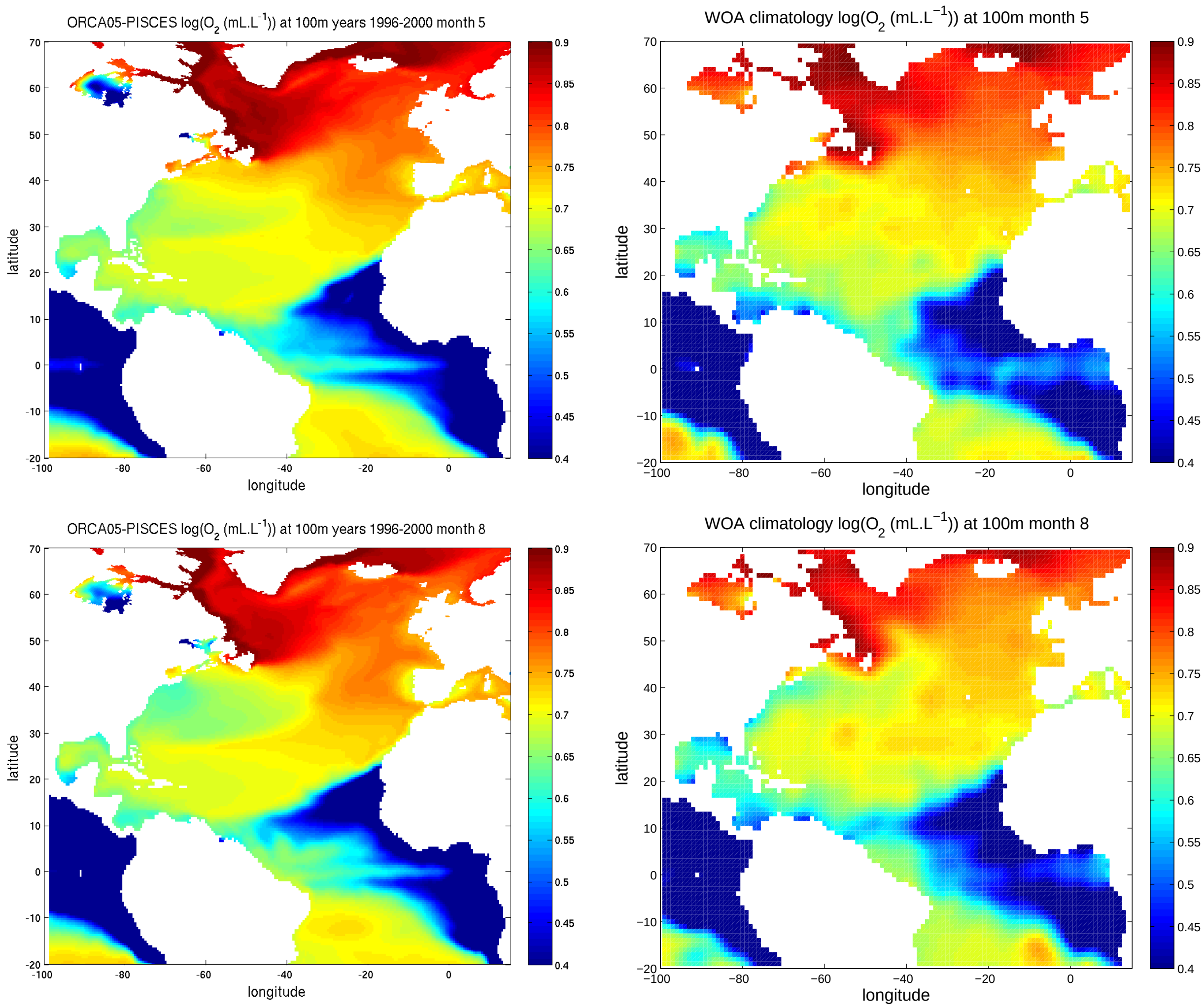

Figure 28: Oxygen at 100m in ORCA05-PISCES years 1996-2000 and WOA05 in may and august

Oxygen sections a 30 °**N**

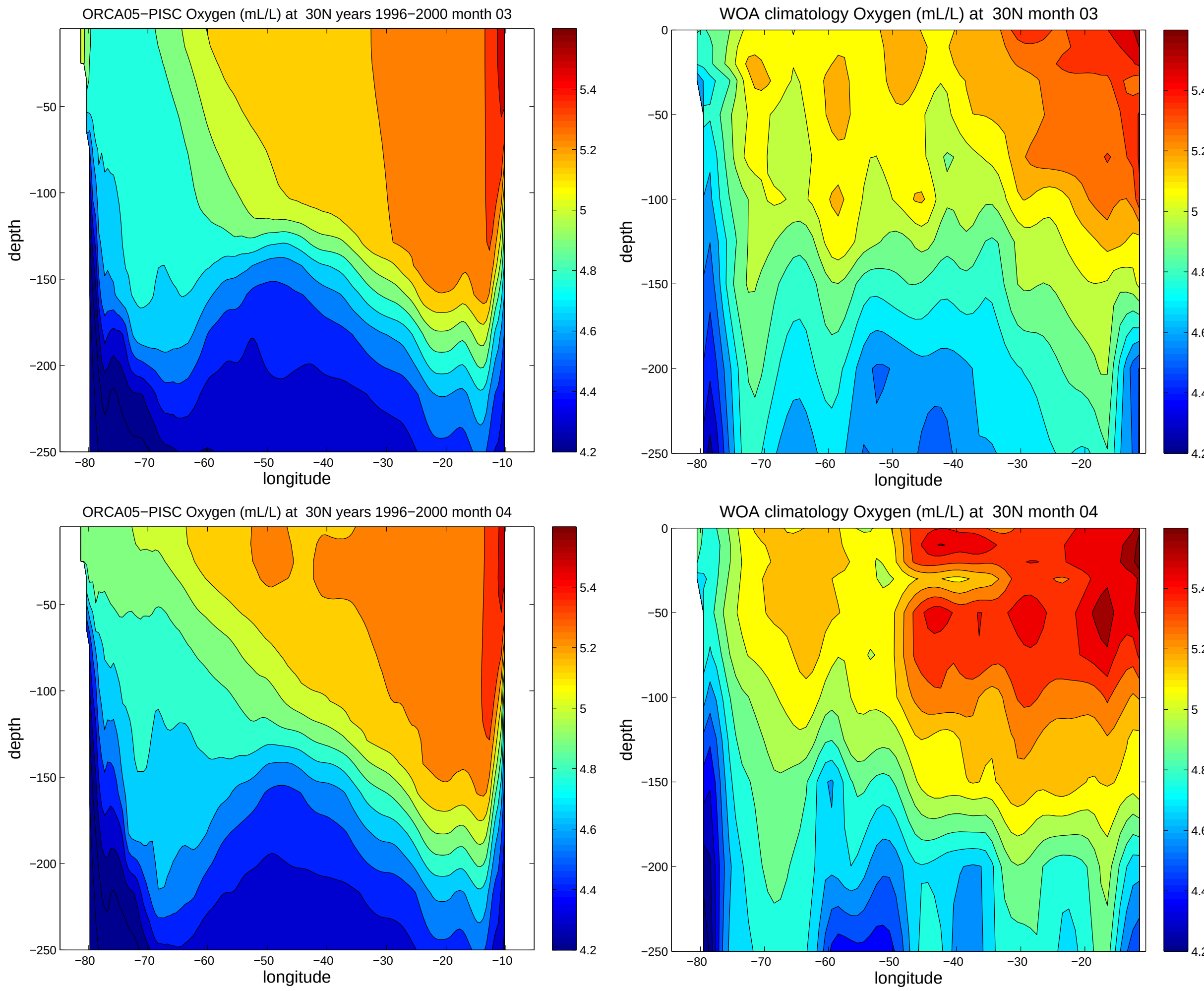

Figure 29: Oxygen section at 30 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in march and april

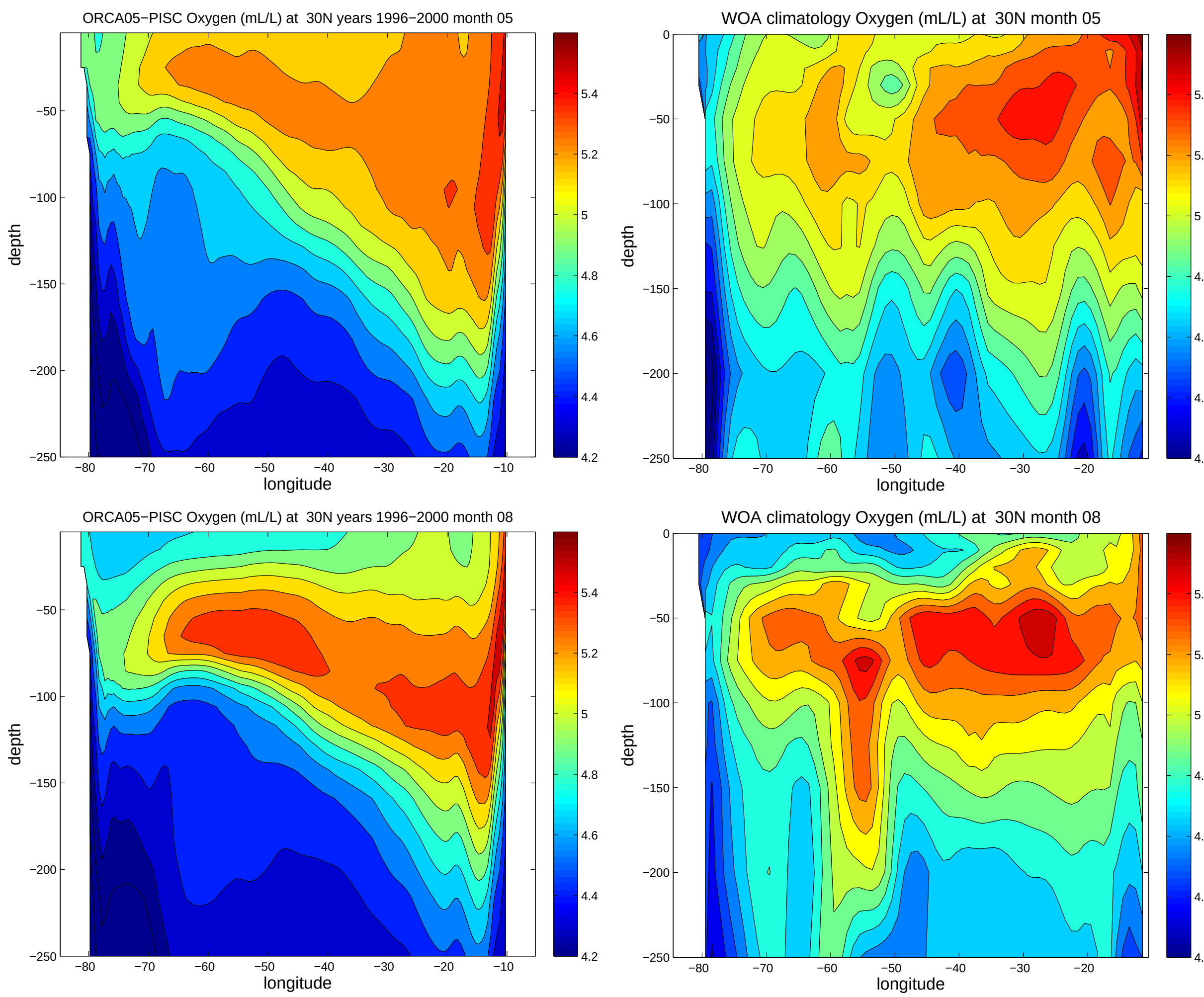

Figure 30: Oxygen section at 30 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in may and august

Oxygen sections a 40 °N

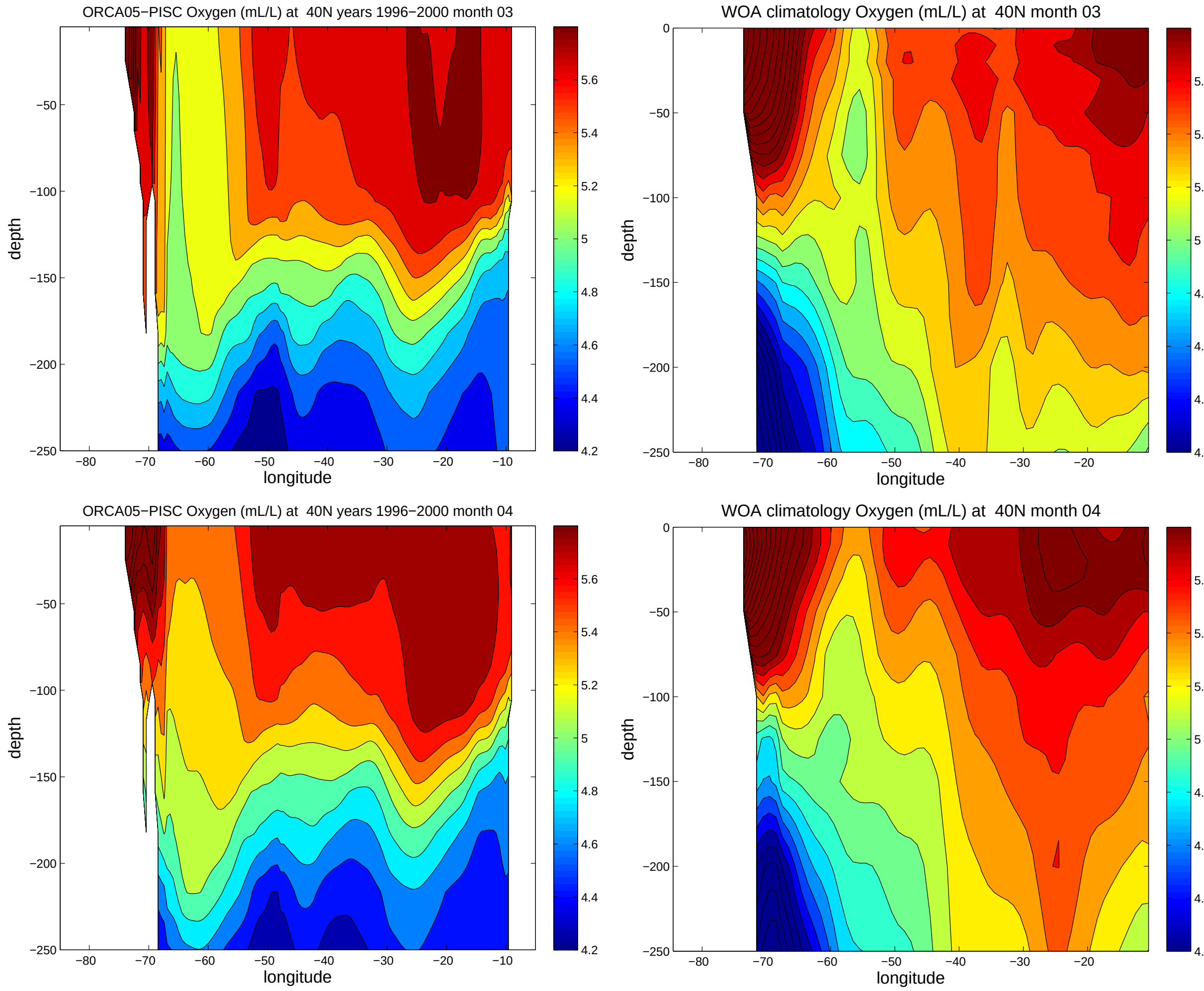

Figure 31: Oxygen section at 40 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in march and april

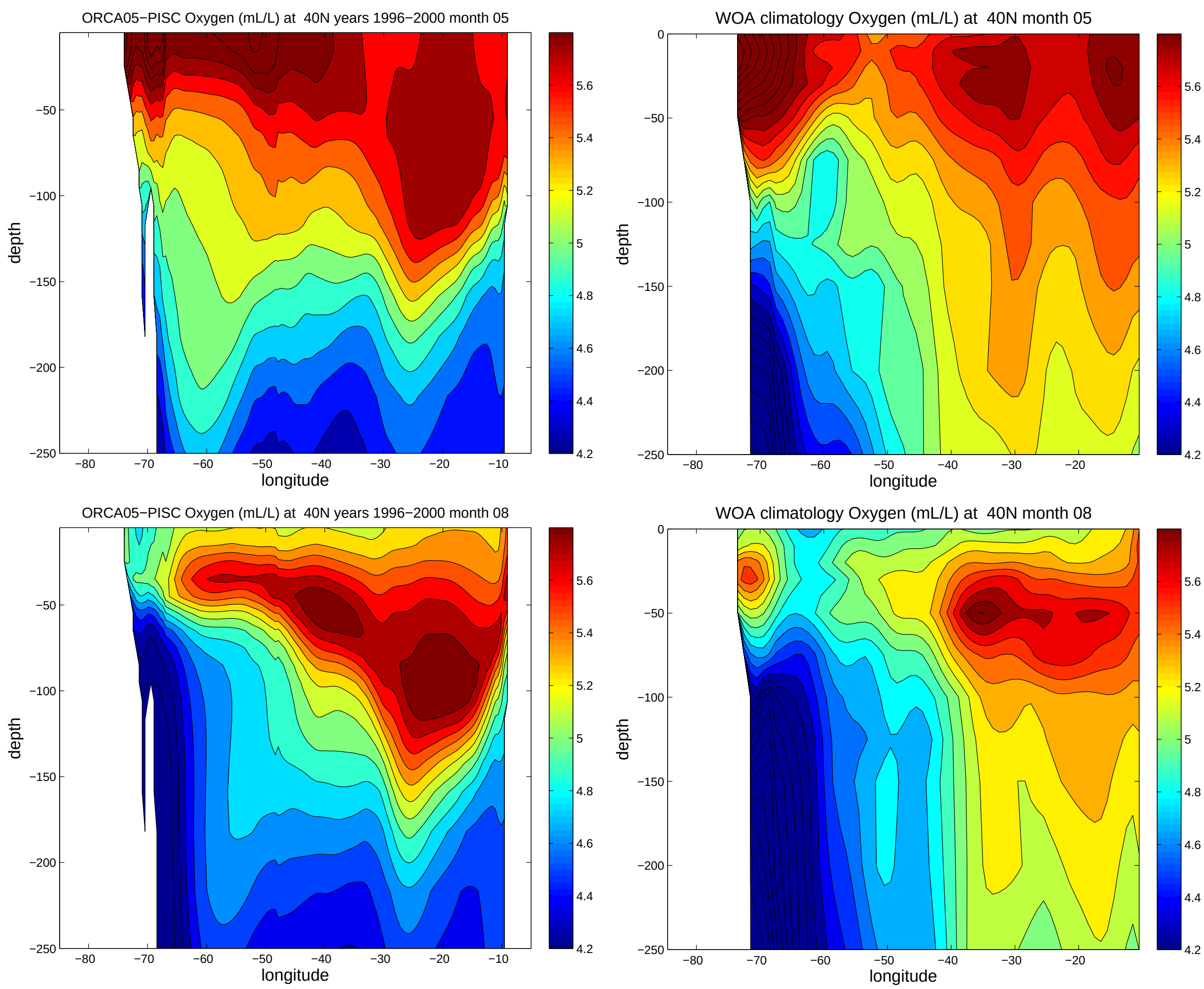

Figure 32: Oxygen section at 40 °N in ORCA05-PISCES years 1996-2000 compared with World Ocean Atlas climatology in may and august

Annex 4 : Chlorophyll plots with linear scale

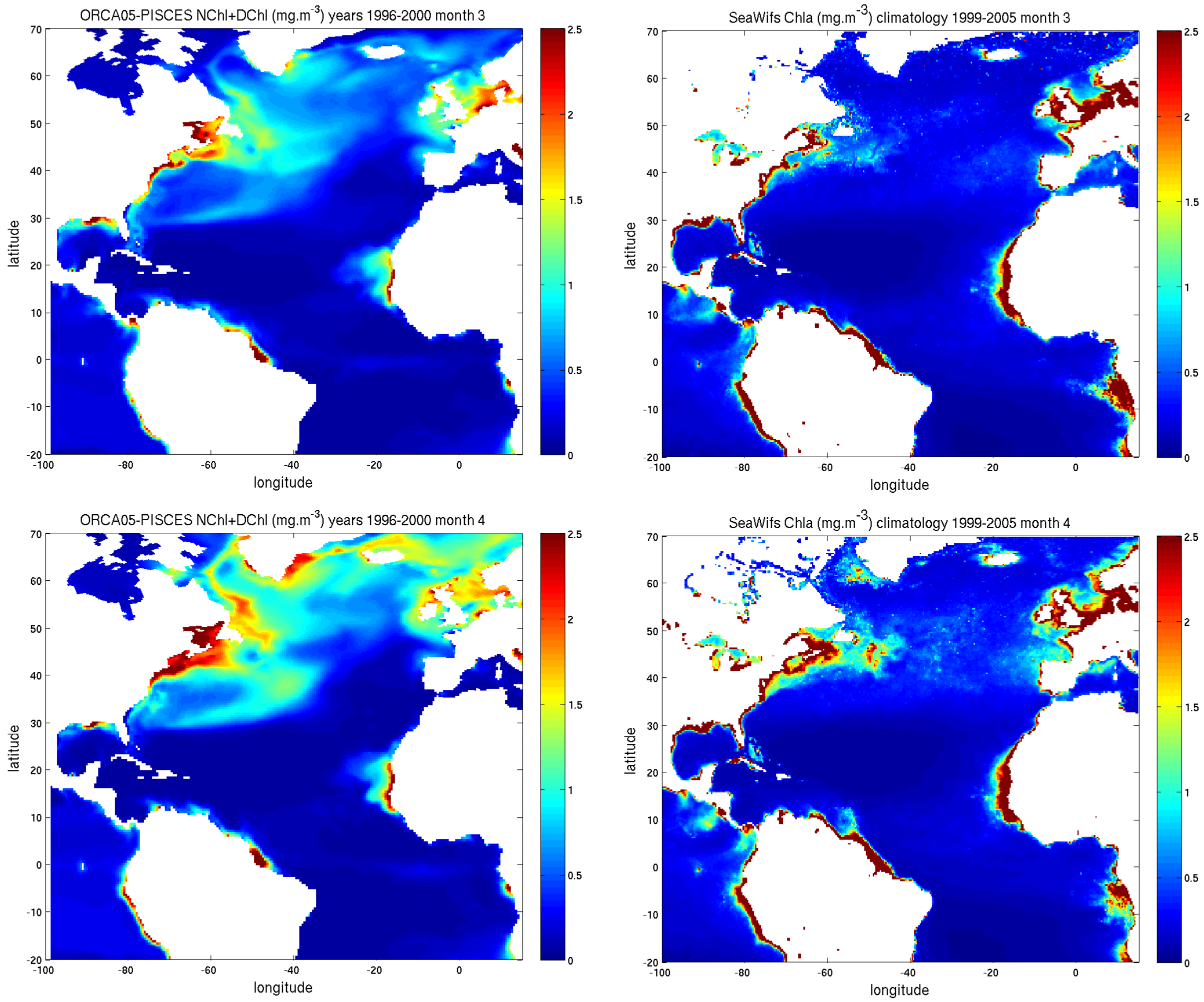

Figure 33: Mean surface chlorophyll in ORCA05-PISCES years 1996-2000 compared with Seawifs climatology in march and april

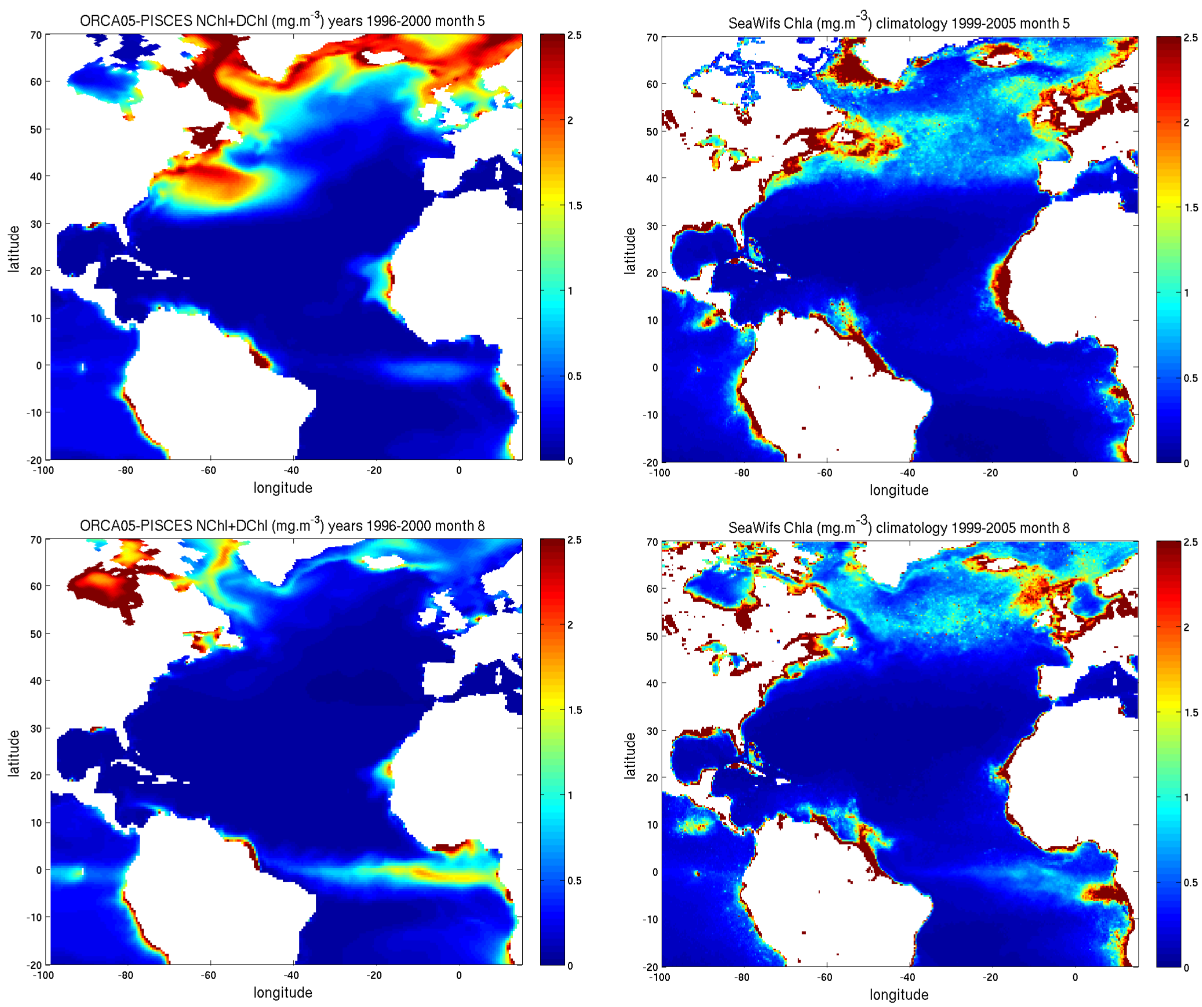

Figure 34: Mean surface chlorophyll in ORCA05-PISCES years 1996-2000 compared with Seawifs climatology in may and august

Annex 5 : Namelist

```
!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
! OPA namelist :  model option and parameter input
! -------------
!>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
!
!-----------------------------------------------------------------------
!       namrun   parameters of the run
!-----------------------------------------------------------------------
!  no         job number
!  cexper     experience name for vairmer format
!  ln_rstart  boolean term for restart (true or false)
!  nrstdt     control of the restart timestep:
!                = 0 restart, do not control nit000 in the restart file.
!                = 1 restart, control nit000 in the restart file. Do not
!                    use the date in the restart file (use ndate0 in namelist)
!                = 2 restart, control nit000 in the restart file, use the date
!                    in the restart file. ndate0 in the namelist is ignored.
!  nit000     number of the first time step
!  nitend     number of the last time step
!  ndate0     initial calendar date aammjj
!  nleapy     Leap year calendar (0/1)
!  ninist     initial state output flag (0/1)
!  nprint     level of print (0 no print)
!  nstock     frequency of restart file
!  nwrite     frequency of OUTPUT file
!  nrunoff    = 0 no, 1 runoff, 2 runoff+river mouth ups adv
!  ln_ctl     trend control print (expensive!)
!  nictls     start i indice to make the control SUM (very usefull to compare mono-
!  nictle     end   i indice to make the control SUM (-versus multi processor runs)
!  njctls     start j indice to make the control SUM (very usefull to compare mono-
!  njctle     end   j indice to make the control SUM (-versus multi processor runs)
!  isplt      number of processors following i
!  jsplt      number of processors following j
!  nbench     Bench parameter (0/1): CAUTION it must be zero except for bench
!             for which we don't care about physical meaning of the results
!
!  CAUTION: for usual run scripts, logical value of
!  *******  ln_rstart must be .true. or .false.
!                     and NOT .TRUE. or .FALSE.
&namrun
   no         =      0
   cexper     =  "ORCA05"
   ln_rstart  = .false.
   nrstdt     =      0
   nit000     =      1
   nitend     =   5475
   ndate0     =  010101
   nleapy     =      0
   ninist     =      0
   nprint     =      0
```

```
   nstock     =    5475
   nwrite     =    5475
   nrunoff    =       2
   ln_ctl     =  .false.
   nictls     =       0
   nictle     =       0
   njctls     =       0
   njctle     =       0
   isplt      =       1
   jsplt      =       1
   nbench     =       0
/
!-----------------------------------------------------------------------
!       nam_mpp      Massively Parallel Processing
!-----------------------------------------------------------------------
!  c_mpi_send         mpi send/recieve type
!                      = 'S'  : standard blocking send
!                      = 'B'  : buffer blocking send
!                      = 'I'  : immediate non-blocking send
&nam_mpp
   c_mpi_send =  'S'
/
!-----------------------------------------------------------------------
!       nam_traadv   advection scheme for tracer (option not control by CPP keys)
!-----------------------------------------------------------------------
!  ln_traadv_cen2     2nd order centered scheme    (default T)
!  ln_traadv_tvd      TVD scheme                   (default F)
!  ln_traadv_muscl    MUSCL scheme                 (default F)
!  ln_traadv_muscl2   MUSCL2 scheme                (default F)
&nam_traadv
   ln_traadv_cen2   =  .false.
   ln_traadv_tvd    =  .true.
   ln_traadv_muscl  =  .false.
   ln_traadv_muscl2 =  .false.
/
!-----------------------------------------------------------------------
!       nam_traldf   lateral diffusion scheme for tracer (option not control by CPP keys)
!-----------------------------------------------------------------------
!  Type of the operator :
!     ln_traldf_lap    laplacian operator          (default T)
!     ln_traldf_bilap  bilaplacian operator        (default F)
!  Direction of action  :
!     ln_traldf_level  iso-level                   (default F)
!     ln_traldf_hor    horizontal (geopotential)   (default F)^**
!     ln_traldf_iso    iso-neutral                 (default T)^*
!  Coefficient
!     aht0    horizontal eddy diffusivity for tracers (m2/s)
!     ahtb0   background eddy diffusivity for isopycnal diffusion (m2/s)
!     aeiv0   eddy induced velocity coefficient (m2/s)
! ^* require key_ldfslp to compute the direction of the lateral diffusion
! ^** require key_ldfslp in s-coordinate
&nam_traldf
```

```
   ln_traldf_lap    =  .true.
   ln_traldf_bilap  =  .false.
   ln_traldf_level  =  .false.
   ln_traldf_hor    =  .false.
   ln_traldf_iso    =  .true.
   aht0    =  1000.
   ahtb0   =     0.
   aeiv0   =  1000.
/
!-----------------------------------------------------------------------
!       nam_dynldf   lateral diffusion on momentum
!-----------------------------------------------------------------------
!  Type of the operator :
!     ln_dynldf_lap    laplacian operator          (default T)
!     ln_dynldf_bilap  bilaplacian operator        (default F)
!  Direction of action  :
!     ln_dynldf_level  iso-level                   (default F)
!     ln_dynldf_hor    horizontal (geopotential)   (default F)^**
!     ln_dynldf_iso    iso-neutral                 (default T)^*
!  Coefficient
!  ahm0    horizontal eddy viscosity for the dynamics (m2/s)
!  ahmb0   background eddy viscosity for isopycnal diffusion (m2/s)
&nam_dynldf
   ln_dynldf_lap    =  .false.
   ln_dynldf_bilap  =  .true.
   ln_dynldf_level  =  .true.
   ln_dynldf_hor    =  .false.
   ln_dynldf_iso    =  .false.
   ahm0    =  -8.5e+11
   ahmb0   =     0.
/
!-----------------------------------------------------------------------
!       namflg   algorithm flags (algorithm not control by CPP keys)
!-----------------------------------------------------------------------
!  ln_dynhpg_imp   hydrostatic pressure gradient: semi-implicit time scheme  (T)
!                                                  centered      time scheme  (F)
&namflg
   ln_dynhpg_imp   =  .true.
/
!-----------------------------------------------------------------------
!       nam_dynvor   option of physics/algorithm (not control by CPP keys)
!-----------------------------------------------------------------------
!  ln_dynvor_ens   vorticity trends: enstrophy conserving scheme (default T)
!  ln_dynvor_ene      "         "  : energy conserving scheme    (default F)
!  ln_dynvor_mix      "         "  : mixed scheme                (default F)
!  ln_dynvor_een      "         "  : energy & enstrophy scheme   (default F)
&nam_dynvor
   ln_dynvor_ene = .FALSE.
   ln_dynvor_ens = .FALSE.
   ln_dynvor_mix = .FALSE.
   ln_dynvor_een = .TRUE.
/
```

```
!---------------------------------------------------------------------
!       namtau   surface wind stress
!---------------------------------------------------------------------
!  ntau000   gently increase the stress over the first ntau_rst time-steps
!  tau0x     uniform value used as default surface heat flux
!  tau0y     uniform value used as default solar radiation flux
&namtau
   ntau000 =      0
   tau0x   =      0.e0
   tau0y   =      0.e0
/
!---------------------------------------------------------------------
!       namflx   surface fluxes
!---------------------------------------------------------------------
!  q0       uniform value used as default surface heat flux
!  qsr0     uniform value used as default solar radiation flux
!  emp0     uniform value used as default surface freswater budget (E-P)
&namflx
   q0      =      0.e0
   qsr0    =      0.e0
   emp0    =      0.e0
/
!---------------------------------------------------------------------
!       namalb   albedo parameters
!---------------------------------------------------------------------
!  cgren    correction of the snow or ice albedo to take into account
!  albice   albedo of melting ice in the arctic and antarctic
!  alphd    coefficients for linear interpolation used to compute albedo
!           between two extremes values (Pyane, 1972)
!  alphc     "                                         "
!  alphdi    "                                         "
&namalb
   cgren    =      0.06
   albice   =      0.5
   alphd    =      0.80
   alphc    =      0.65
   alphdi   =      0.72
/
!---------------------------------------------------------------------
!       namdom   space and time domain (bathymetry, mesh, timestep)
!---------------------------------------------------------------------
!  ntopo      = 0/1 ,compute/read the bathymetry file
!               (mbathy, nb of T-ocean levels)
!  e3zps_min  the thickness of the partial step is set larger than the
!  e3zps_rat     the minimum of e3zps_min and e3zps_rat * e3t
!                (N.B. 0<e3zps_rat<1)
!  ngrid      = 0/1, compute/read the horizontal mesh
!                  (coordinates, scale factors)
!  nmsh       =1 create a mesh file (coordinates, scale factors, masks)
!  nacc       the acceleration of convergence method
!             = 0, no acceleration, rdt = rdttra
!             = 1, acceleration used, rdt < rdttra(k)
```

```
!  atfp       asselin time filter parameter
!  rdt        time step for the dynamics (and tracer if nacc=0)
!  rdtmin     minimum time step on tracers
!  rdtmax     maximum time step on tracers
!  rdth       depth variation of tracer time step
!  nfice      frequency of ice model call
!  nfbulk     frequency of bulk formulea call (not used if ice used)
!  nclosea    = 0 no closed sea
!             = 1 closed sea (Black Sea, Caspian Sea, Great US Lakes...)
&namdom
   ntopo     =     1
   e3zps_min =     25.
   e3zps_rat =     0.2
   ngrid     =     1
   nmsh      =     1
   nacc      =     0
   atfp      =     0.1
   rdt       =  2160.
   rdtmin    =  2160.
   rdtmax    =  2160.
   rdth      =   800.
   nfice     =     5
   nfbulk    =     5
   nclosea   =     0
/
!-----------------------------------------------------------------------
!       namfwb   freshwater budget correction
!-----------------------------------------------------------------------
!  ln_fwb     logical flag for freshwater budget correction (0 annual mean)
&namfwb
   ln_fwb    = .false.
/
!-----------------------------------------------------------------------
!       namptr   Poleward Transport Diagnostic
!-----------------------------------------------------------------------
!  ln_diaptr  logical flag for Poleward transport computation
!  nf_ptr     Frequency of computation
&namptr
   ln_diaptr = .false.
   nf_ptr    =  15
/
!-----------------------------------------------------------------------
!       namcro   cross land advection
!-----------------------------------------------------------------------
!  n_cla   advection between 2 ocean pts separates by land
&namcla
   n_cla   = 0
/
!-----------------------------------------------------------------------
!       namzdf   vertical physics
!-----------------------------------------------------------------------
!  ln_zdfevd  enhanced vertical diffusion         (default T)
```

```
!  ln_zdfnpc  Non-Penetrative Convection          (default T)
!  avm0       vertical eddy viscosity for the dynamic (m2/s)
!  avt0       vertical eddy diffusivity for tracers (m2/s)
!  avevd      vertical coefficient for enhanced diffusion scheme (m2/s)
!  nevdm      = 0  apply enhanced mixing on tracer only
!             = 1  apply enhanced mixing on both tracer and momentum
!  ln_zdfexp   vertical physics: (=T)  time splitting (T)     (Default=F)
!                                (=F)  euler backward (F)
!  n_zdfexp   number of sub-timestep for time splitting scheme
&namzdf
   ln_zdfevd = .true.
   ln_zdfnpc = .false.
   avm0     = 1.e-4
   avt0     = 1.e-5
   avevd    =   10.
   nevdm    =     1
   ln_zdfexp =  .false.
   n_zdfexp =      3
/
!-----------------------------------------------------------------------
!       namnpc   vnon penetrative convection
!-----------------------------------------------------------------------
!  nnpc1   non penetrative convective scheme frequency
!  nnpc2   non penetrative convective scheme print frequency
&namnpc
   nnpc1  =      1
   nnpc2  =    365
/
!-----------------------------------------------------------------------
!       nambbl   bottom boundary layer scheme
!-----------------------------------------------------------------------
!  atrbbl   lateral tracer coeff. for bottom boundary layer scheme(m2/s)
&nambbl
   atrbbl = 6000.
/
!-----------------------------------------------------------------------
!       namric   richardson number dependent vertical diffusion
!                ( #ifdef "key_zdfrichardson" )
!-----------------------------------------------------------------------
!  avmri   maximum value of the vertical viscosity
!  alp     coefficient of the parameterization
!  nric    coefficient of the parameterization
&namric
   avmri = 100.e-4
   alp   =      5.
   nric  =      2
/
!-----------------------------------------------------------------------
!       namtke   turbulent eddy kinetic dependent vertical diffusion
!                ( #ifdef "key_zdftke" )
!-----------------------------------------------------------------------
!  ln_rstke flag to restart with tke from a run without tke (default F)
```

```
!  ediff    coef. to compute vertical eddy coef. (avt=ediff*mxl*sqrt(e) )
!  ediss    coef. of the Kolmogoroff dissipation
!  ebb      coef. of the surface input of tke
!  efave    coef. to applied to the tke diffusion ( avtke=efave*avm )
!  emin     minimum value of tke (m^2/s^2)
!  emin0    surface minimum value of tke (m^2/s^2)
!  nitke    number of restart iterative loops
!  ri_c     critic richardson number
!  nmxl     flag on mixing length used
!           = 0 bounded by the distance to surface and bottom
!           = 1 bounded by the local vertical scale factor
!           = 2 first vertical derivative of mixing length bounded by 1
!  npdl     flag on prandtl number
!           = 0 no vertical prandtl number (avt=avm)
!           = 1 prandtl number function of richarson number (avt=pdl*avm)
!           = 2 same as = 1 but a shapiro filter is applied on pdl
!  nave     =  horizontal averaged (=1) or not (=0) of avt  (default =1)
!  navb     = 0 cst background avt0, avm0 / =1 profile used on avtb
&namtke
   ln_rstke = .false.
   ediff =       0.1
   ediss =       0.7
   ebb   =       60
   efave =        1.
   emin  =     1.e-6
   emin0 =     1.e-4
   nitke =        50
   nmxl  =         2
   npdl  =         1
   navb  =         0
   nave   =        1
   ln_lsfc =  .true.
   lmin    =    0.4
   n_etau =       1
   nhtau  =       1
   fr_emin =     0.05
   ln_lc =   .true.
   c_lc  =    0.15
/
!-----------------------------------------------------------------------
!       namkpp   K-Profile Parameterization dependent vertical diffusion
!                ( #ifdef "key_zdfkpp" )
!-----------------------------------------------------------------------
!  ln_kpprimix   shear instability mixing  (default T)
!  difmiw        constant internal wave viscosity (m2/s)
!  difsiw        constant internal wave diffusivity (m2/s)
!  Riinfty       local Richardson Number limit for shear instability
!  difri         maximum shear mixing at Rig = 0    (m2/s)
!  bvsqcon       Brunt-Vaisala squared (1/s**2) for maximum convection
!  difcon        maximum mixing in interior convection (m2/s)
!  nave          = 0/1 flag for horizontal average on avt, avmu, avmv
!  navb          = 0/1 flag for constant or profile background avt
```

```
&namkpp
   ln_kpprimix  = .true.
   difmiw       =  1.e-04
   difsiw       =  0.1e-04
   Riinfty      =  0.8
   difri        =  0.0050
   bvsqcon      = -0.01e-07
   difcon       =  1.
   navb         =  0
   nave         =  1
/
!-----------------------------------------------------------------------
!       namddm   double diffusive mixing parameterization
!-----------------------------------------------------------------------
!   avts    maximum avs for dd mixing
!   hsbfr   heat/salt buoyancy flux ratio
&namddm
      avts  = 1.e-4
      hsbfr = 1.6
/
!-----------------------------------------------------------------------
!       namlbc   lateral momentum boundary condition
!-----------------------------------------------------------------------
!  shlat   lateral boundary condition on velocity
!                   shlat = 0 , free slip
!               0 < shlat < 2 , partial slip
!                   shlat = 2 , no slip
!               2 < shlat     , strong slip
&namlbc
   shlat  =      0.
/
!-----------------------------------------------------------------------
!       nambfr   bottom friction
!-----------------------------------------------------------------------
!  nbotfr  type of bottom friction
!                  nbotfr = 0 , no slip
!                  nbotfr = 1 , linear friction
!                  nbotfr = 2 , nonlinear friction
!                  nbotfr = 3 , free slip
!  bfri1   bottom drag coefficient (linear case)
!  bfri2   bottom drag coefficient (non linear case)
!  bfeb2   bottom turbulent kinetic energy  (m^2/s^2)
&nambfr
   nbotfr =      2
   bfri1  =   4.e-4
   bfri2  =   1.e-3
   bfeb2  =  2.5e-3
/
!-----------------------------------------------------------------------
!       nambbc   bottom temperature boundary condition
!-----------------------------------------------------------------------
!  ngeo_flux  = 0 no geothermal heat flux
```

```
!             = 1 constant geothermal heat flux
!             = 2 variable geothermal heat flux (read in geothermal_heating.nc)
!                 ( C A U T I O N : flux in mW/m2 in the NetCDF file )
!  ngeo_flux_const   Constant value of geothermal heat flux (W/m2)
&nambbc
   ngeo_flux = 1
   ngeo_flux_const = 88.4e-3
/
!-----------------------------------------------------------------------
!       namqsr   penetrative solar radiation
!-----------------------------------------------------------------------
!  ln_traqsr : penetrative solar radiation (T) or not (F)     (Default=T)
!  rabs       fraction of qsr associated with xsi1
!  xsi1       first depth of extinction
!  xsi2       second depth of extinction
&namqsr
   ln_traqsr = .true.
   rabs     =   0.58
   xsi1     =   0.35
   xsi2     =   23.0
   ln_qsr_sms =  .false.
/
!-----------------------------------------------------------------------
!       namtdp   tracer newtonian damping ('key_tradmp')
!-----------------------------------------------------------------------
!  ndmp    type of damping in temperature and salinity
!          (='latitude', damping poleward of 'ndmp' degrees and function
!             of the distance-to-coast. Red and Med Seas as ndmp=-1)
!          (=-1 damping only in Med and Red Seas)
!  ndmpf   =1 create a damping.coeff NetCDF file (the 3D damping array)
!  nmldmp  type of damping in the mixed layer
!          (=0 damping throughout the water column)
!     (=1 no damping in the mixed layer defined by avt >5cm2/s )
!     (=2 no damping in the mixed layer defined rho<rho(surf)+.01 )
!  sdmp    surface time scale for internal damping (days)
!  bdmp    bottom time scale for internal damping (days)
!  hdmp    depth of transition between sdmp and bdmp (meters)
&namtdp
   ndmp   =   -1
   ndmpf  =    1
   nmldmp =    0
   sdmp   =  50.
   bdmp   = 360.
   hdmp   = 800.
/
!-----------------------------------------------------------------------
!       nameos   ocean physical parameters
!-----------------------------------------------------------------------
!  neos    type of equation of state and Brunt-Vaisala frequency
!          = 0, UNESCO (formulation of Jackett and McDougall (1994)
!                                         and of McDougall (1987) )
!          = 1, linear: rho(T)   = rau0 * ( 1.028 - ralpha * T )
```

```
!          = 2, linear: rho(T,S) = rau0 * ( rbeta * S - ralpha * T )
!                               with rau0=1020 set in parcst routine
!  ralpha  thermal expension coefficient (linear equation of state)
!  rbeta   saline  expension coefficient (linear equation of state)
&nameos
   neos   =      0
   ralpha =  2.e-4
   rbeta  =  0.001
/
!-----------------------------------------------------------------------
!       namsol   elliptic solver / island / free surface
!-----------------------------------------------------------------------
!  nsolv     elliptic solver (=1 preconditioned conjugate gradient: pcg)
!                            (=2 successive-over-relaxation: sor)
!                            (=3 FETI: fet, all require "key_feti" defined)
!                            (=4 sor with extra outer halo))
!  nsol_arp  absolute/relative (0/1) precision convergence test
!  nmin      minimum of iterations for the SOR solver
!  nmax      maximum of iterations for the SOR solver
!  nmod      frequency of test for the SOR solver
!  eps       absolute precision of the solver
!  resmax    absolute precision for the SOR solver
!  sor       optimal coefficient for SOR solver
!  epsisl    absolute precision on stream function solver
!  nmisl     maximum pcg iterations for island
!  rnu       strength of the additional force used in free surface b.c.
&namsol
   nsolv     =      2
   nsol_arp  =      0
   nmin      =      0
   nmax      =    800
   nmod      =      5
   eps       =  1.E-6
   resmax    = 1.E-11
   sor       =  1.964
   epsisl    = 1.e-10
   nmisl     =   4000
   rnu       =     1.
/
!=======================================================================
!   Diagnostics namelists
!       namtrd    dynamics and/or tracer trends
!       namgap    level mean model-data gap
!       namznl    zonal mean heat & freshwater fluxes computation
!       namspr    surface pressure in rigid-lid
!=======================================================================
!-----------------------------------------------------------------------
!       namtrd    diagnostics on dynamics and/or tracer trends
!                         ('key_diatrdyn' and/or 'key_diatrtra')
!                 or mixed-layer trends ('key_diatrdmld')
!-----------------------------------------------------------------------
!  ntrd    time step frequency dynamics and tracers trends
```

```
!  nctls   control surface type in mixed-layer trends (0,1 or n<jpk)
&namtrd
   ntrd  = 365
   nctls =   0
/
!-----------------------------------------------------------------------
!       namgap    level mean model-data gap ('key_diagap')
!-----------------------------------------------------------------------
!  ngap    time-step frequency of model-data gap computation
!  nprg    time-step frequency of gap print in model output
&namgap
   ngap =  15
   nprg =  10
/
!-----------------------------------------------------------------------
!       namznl    zonal mean heat & freshwater fluxes computation
!                 (#ifdef "key_diaznl")
!-----------------------------------------------------------------------
!  nfznl   time-step frequency of zonal mean fluxes computation
&namznl
   nfznl =  15
/
!-----------------------------------------------------------------------
!       namspr  surface pressure diagnostic
!-----------------------------------------------------------------------
!  nmaxp   maximum of iterations for the solver
!  epsp    absolute precision of the solver
!  niterp  number of iteration done by the solver
&namspr
   nmaxp   =   1000
   epsp    =  1.e-3
   niterp  =    400
/
!-----------------------------------------------------------------------
!       namcpl    coupled ocean/atmosphere model  (#ifdef "key_coupled")
!-----------------------------------------------------------------------
!  nexco   coupling frequency in time steps
!  cchan   coupling technique 'PIPE' or 'CLIM'
&namcpl
   nexco          =        24
   cchan          =    'PIPE'
   nmodcpl        =         2
   cplmodnam      =   'opa.xx'
   cploasis       =    'Oasis'
   nfldo2c        =         2
   nflxc2o        =         6
   ntauc2o        =         4
   cpl_writ(1)    = 'SOSSTSST'
   cpl_f_writ(1)  =   'ocesst'
   cpl_writ(2)    = 'SOICECOV'
   cpl_f_writ(2)  =   'oceice'
   cpl_readflx(1) = 'SONSFLDO'
```

```
   cpl_f_readflx(1) =   'oceflx'
   cpl_readflx(2)   = 'SOSHFLDO'
   cpl_f_readflx(2) =   'oceflx'
   cpl_readflx(3)   = 'SOTOPRSU'
   cpl_f_readflx(3) =   'oceflx'
   cpl_readflx(4)   = 'SOTFSHSU'
   cpl_f_readflx(4) =   'oceflx'
   cpl_readflx(5)   = 'SORUNCOA'
   cpl_f_readflx(5) =   'oceflx'
   cpl_readflx(6)   = 'SORIVFLU'
   cpl_f_readflx(6) =   'oceflx'
   cpl_readtau(1)   = 'SOZOTAUX'
   cpl_f_readtau(1) =   'ocetau'
   cpl_readtau(2)   = 'SOZOTAU2'
   cpl_f_readtau(2) =   'ocetau'
   cpl_readtau(3)   = 'SOMETAUY'
   cpl_f_readtau(3) =   'ocetau'
   cpl_readtau(4)   = 'SOMETAU2'
   cpl_f_readtau(4) =   'ocetau'
/
!-----------------------------------------------------------------------
!       namobc    open boundaries parameters (#ifdef key_obc)
!-----------------------------------------------------------------------
!  nobc_dta   = 0 the obc data are equal to the initial state
!             = 1 the obc data are read in 'obc   .dta' files
!  rdpeob  time relaxation (days) for the east open boundary
!  rdpwob  time relaxation (days) for the west open boundary
!  rdpnob  time relaxation (days) for the north open boundary
!  rdpsob  time relaxation (days) for the south open boundary
!  zbsic1  barotropic stream function on isolated coastline 1
!   zbsic2  barotropic stream function on isolated coastline 2
!  zbsic3  barotropic stream function on isolated coastline 3
&namobc
    nobc_dta =    0
    rdpein   =    1.
    rdpwin   =    1.
    rdpnin   =   30.
    rdpsin   =    1.
    rdpeob   = 1500.
    rdpwob   =   15.
    rdpnob   =  150.
    rdpsob   =   15.
    zbsic1   =  140.e+6
    zbsic2   =    1.e+6
    zbsic3   =    0.
/
!-----------------------------------------------------------------------
!       namflo    float parameters (#ifdef key_float)
!-----------------------------------------------------------------------
!  ln_rstflo   boolean term for float restart (true or false)
!  nwritefl   frequency of float output file
!  nstockfl   frequency of float restart file
```

```
!  ln_argo    Argo type floats (stay at the surface each 10 days)
!  ln_flork4  = T trajectories computed with a 4th order Runge-Kutta
!             = F  (default)   computed with Blanke' scheme
&namflo
    ln_rstflo = .false.
    nwritefl  =      75
    nstockfl  =    5475
    ln_argo   = .false.
    ln_flork4 = .false.
/
```

Annex 6 : CPP Keys

```
key_mpp_mpi
key_partial_steps
key_trabbl_dif
key_vectopt_loop
key_vectopt_memory
key_orca_r05
key_ice_lim
key_lim_fdd
key_dynspg_fsc
key_diaeiv
key_ldfslp
key_traldf_c2d
key_traldf_eiv
key_dynldf_c2d
key_dtatemp
key_dtasal
key_tau_daily
key_flx_bulk_daily
key_tradmp
key_trabbc
key_zdftke
key_zdfddm
key_passivetrc
key_trc_pisces
key_trcbbl_dif
key_trc_zdfddm
key_trc_dta
key_trc_ldfeiv
key_trc_dia3d
key_trc_diaadd
```