Definition of the interannual experiment ORCA12.L46-MAL95, 1989-2007

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Introduction

This report describes in details the ORCA12.L46-MAL95 simulation performed in the frame of the DRAKKAR project. This run is the first ORCA12 simulation computed at MEOM (LEGI, CNRS). The mesh is an ORCA grid 1/12° at equator, with partial-steps, 46 levels Drakkar type. It is a following of the Kiel (IFM Geomar) ORCA12.L46-K001 run (started in 1978 from Levitus) but we change the forcing fields from CORE2 to ERA-interim. The purposes of this run are thus to learn how to run such a big model and to perform a sensitivity experiment between CORE2 (K001) and ERA-interim forcing. The code is based on version NEMO 3.2.2.

This report is organized in different sections. The first one deals with the details of the numerical code, the parametrizations used and the forcing issues. The second section describes the model configuration, e.g. the model grid and the input data of the model. A third section is dedicated to the technical details of the production of the run and give some informations about the computing performance. Finally, the last section gives some elements of validation of the run.

1 Numerical code

1.1 Overview

This experiment was performed with version 3.2.2 of NEMO. CPP keys used for compilation are:

CPP key name	**Action:**
key_orca_r12	ORCA12 horizontal grid with 46 vertical levels
key_dynspg_flt	Filtered free surface
key_zdftke	Tke turbulent closure for vertical diffusion
key_dtatem	Initialize model from temperature climatology
key_dtasal	Initialize model from salinity climatology
key_traldf_c2d	2D horizontal dependency on lateral diffusivity
key_dynldf_c2d	2D horizontal dependency on lateral viscosity
key_ldfslp	Compute isopycnal slopes
key_dimgout	Use temporary binary files for mpp output
key_mpp_mpi	Parallel processing using MPI library
key_lim2	Use LIM2 ice model
key_trabbl_dif	Use BBL enhanced diffusion on tracers

1.2 Ocean details

1.2.1 Vertical physics

TKE scheme

TKE is used to determine the vertical diffusion coefficient. The relevant namelist data are indicated below. Note that in this version, a non-standard treatment is performed on ice-covered area: (a) The background avt coefficient is divided by 10 under ice. (b) There is no background of Tke under ice. (c) The coefficient for surface input of tke (ebb) is reduced from 60 (open ocean) to 3.75 (ice covered regions). (d) Lang-Muir cells parametrization is turned off below ice.

```
!-----------------------------------------------------------------------------------------------
&namzdf        !   vertical physics
!-----------------------------------------------------------------------------------------------
   rn_avm0     =  1.2e-4   !  vertical eddy viscosity   [m2/s] (background Kz if not "key_zdfcst")
   rn_avt0     =  1.2e-5   !  vertical eddy diffusivity [m2/s] (background Kz if not "key_zdfcst")
   nn_avb      =    0      !  profile for background avt & avm (=1) or not (=0)
   nn_havtb    =    1      !  horizontal shape for avtb (=1) or not (=0)
   ln_zdfevd   = .true.    !  convection: enhanced vertical diffusion (T) or not (F)
   nn_evdm     =    1      !  enhanced mixing apply on tracer (=0) or on tracer and momentum (=1)
   rn_avevd    =   10.     !  vertical coefficient for enhanced diffusion scheme [m2/s]
   ln_zdfnpc   = .false.   !  convection: Non-Penetrative algorithm (T) or not (F)
   nn_npc      =    1      !  frequency of application of npc
   nn_npcp     =   365     !  npc control print frequency
   ln_zdfexp   = .false.   !  split explicit (T) or implicit (F) time stepping
   nn_zdfexp   =    3      !  number of sub-timestep for ln_zdfexp=T
/

!-----------------------------------------------------------------------------------------------------------------
&namzdf_tke   !   turbulent eddy kinetic dependent vertical diffusion  ("key_zdftke")
!-----------------------------------------------------------------------------------------------------------------
   rn_ediff  = 0.1    !  coef. for vertical eddy coef. (avt=rn_ediff*mxl*sqrt(e))
   rn_ediss  = 0.7    !  coef. of the Kolmogoroff dissipation
   rn_ebb    = 60     !  coef. of the surface input of tke
   rn_ebbice = 3.75   !  coef. of the surface input of tke under ice
   rn_emin   = 1.e-6  !  minimum value of tke [m2/s2]
   rn_emin0  = 1.e-4  !  surface minimum value of tke [m2/s2]
   rn_bshear = 1.e-20 !  background shear (>0)
   nn_mxl    = 3      !  mixing length: = 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
                      !                 = 3 same criteria as case 2 but applied in a different way
   nn_pdl    = 1      !  Prandtl number function of richarson number (=1, avt=pdl(Ri)*avm) or not (=0, avt=avm)
   ln_mxl0   = .true. !  mixing length scale surface value as function of wind stress (T) or not (F)
   rn_lmin   = 0.001  !  interior buoyancy lenght scale minimum value
   rn_lmin0  = 0.01   !  surface  buoyancy lenght scale minimum value
   nn_havti  = 0      !  background modified under ice or not (0/1)
   nn_etau   = 1      !  exponentially deceasing penetration of tke due to internal & intertial waves
                      !  = 0 no penetration ( O(2 km) resolution)
                      !  = 1 additional tke source (rn_efr * en)
                      !  = 2 additional tke source (rn_efr * en) applied only at the base of the mixed layer
                      !  = 3 additional tke source (HF contribution: mean of stress module - module of mean stress)
   nn_htau   = 1      !  type of exponential decrease of tke penetration
                      !        = 0  constant 10 m length scale
                      !        = 1  0.5m at the equator to 30m at high latitudes
                      !        = 2  30 meters constant depth penetration
                      !        = 3 deprecated with 3.2.1 (  DRAKKAR customization)
              ! option used only id nn_etau /= 0
   rn_efr    = 0.05   !  fraction of surface tke value which penetrates inside the ocean
              ! option used only if nn_etau = 3
   rn_addhft = -1.e-3 !  add offset   applied to the "mean of stress module - module of mean stress" (always kept > 0)
   rn_sclhft = 1.     !  scale factor applied to the "mean of stress module - module of mean stress"
   ln_lc     = .true. !  Langmuir cell effect
   rn_lc     = 0.15   !  coef. associated to Langmuir cells
/
```

1.2.2 Horizontal physics

Tracers

We use a laplacian isopycnal diffusivity for tracers. The diffusivity is proportionnal to the local grid size (it decreases poleward). The horizontal eddy diffusivity for tracers is reduced to 125 m^2/s for ORCA12 configuration (compared to ORCA025 : 300 m^2/s).

```
!-----------------------------------------------------------------------------------------------
&namtra_ldf    !   lateral diffusion scheme for tracer
!-----------------------------------------------------------------------------------------------
!                          !  Type of the operator :
   ln_traldf_lap    =  .true.   !     laplacian operator
   ln_traldf_bilap  =  .false.  !     bilaplacian operator
                           !  Direction of action  :
   ln_traldf_level  =  .false.  !     iso-level
   ln_traldf_hor    =  .false.  !     horizontal (geopotential)         (require "key_ldfslp" when ln_sco=T)
   ln_traldf_iso    =  .true.   !     iso-neutral                       (require "key_ldfslp")
!                          !  Coefficient
   rn_aht_0         =  125.     !     horizontal eddy diffusivity for tracers [m2/s]
   rn_ahtb_0        =    0.     !     background eddy diffusivity for ldf_iso [m2/s]
   rn_aeiv_0        =    0.     !     eddy induced velocity coefficient [m2/s]    (require "key_traldf_eiv")
/
```

Momentum

We use a bi-harmonic viscosity for the lateral dissipation. Note that in the ORCA12 configuration, the viscosity is reduced by a factor 14 compared to ORCA025 configuration. The viscosity is proportionnal to the grid size power 3.

```
!-------------------------------------------------------------------------------------------
&namdyn_ldf    !   lateral diffusion on momentum
!-------------------------------------------------------------------------------------------
!                          !  Type of the operator :
   ln_dynldf_lap    =  .false.  !     laplacian operator
   ln_dynldf_bilap  =  .true.   !     bilaplacian operator
!                          !  Direction of action  :
   ln_dynldf_level  =  .false.  !     iso-level
   ln_dynldf_hor    =  .true.   !     horizontal (geopotential)        (require "key_ldfslp" in s-coord.)
   ln_dynldf_iso    =  .false.  !     iso-neutral                      (require "key_ldfslp")
                           !  Coefficient
   rn_ahm_0    = -1.25e10       !     horizontal eddy viscosity if lap : >0  [m2/s]
                                !                            if bilap : <0  [m4/s2]
   rn_ahmb_0   =     0.         !     background eddy viscosity for ldf_iso [m2/s]
!  cn_dynldfahm0 = "ahmcoef"  ! filename for horizontal varying coefficient ahm_0 (key_ldfdyn_c2d/_c3d)
/
```

1.2.3 Bottom Boundary Layer

We used bottom boundary layer parametrization ([1]). Only diffusive (not advective) BBL parametrization is used for tracers, and no BBL advection parametrization for momentum [1].

```
!-------------------------------------------------------------------------------------
&nambbl        !   bottom boundary layer scheme
!-------------------------------------------------------------------------------------
!                          !  diffusive bbl                           ("key_trabbl")
!                          !  advective bbl                           ("key_trabbl_adv")
   rn_ahtbbl     =  1000.  !  lateral mixing coefficient in the bbl  [m2/s]
   ln_kriteria   = .true.  !  activate BBL on k-criteria instead of depth criteria
   ln_counter    = .false. !  save BBL counts [T] or not [F]
/
```

[1]We don't apply the improvement on BBL parametrization proposed in [2] as for MJM95 simulation.

1.2.4 Surface boundary conditions

The surface boundary conditions are prescribed to the model using the CORE bulk formulation. The initial part of the run: K001 ([5]), performed by IFM-Geomar (Kiel) group from 01/01/1978 to 31/12/1988 (and after...) used CORE II forcing. The following part of the run: MAL95, from 01/01/1989 to end (31/12/2007), was forced by ERA-interim reanalysis products (just as ORCA025.L75-MJM95). The data set includes 4 turbulent variables (u10, v10, t2, q2) given every 3 hours, 2 radiative fluxes variables (radsw, radlw), 2 fresh water flux variables (total precipitations, snow) and the total cloud cover (tcc), all these last variables given as daily averaged.

```
!-----------------------------------------------------------------------------------------------------------
&namsbc       !   Surface Boundary Condition (surface module)
!-----------------------------------------------------------------------------------------------------------
   nn_fsbc     = 6        !  frequency of surface boundary condition computation
                          !                (= the frequency of sea-ice model call)
   ln_ana      = .false.  !  analytical formulation (T => fill namsbc_ana )
   ln_flx      = .false.  !  flux formulation       (T => fill namsbc_flx )
   ln_blk_clio = .false.  !  CLIO bulk formulation  (T => fill namsbc_clio)
   ln_blk_core = .true.   !  CORE bulk formulation  (T => fill namsbc_core)
   ln_cpl      = .false.  !  Coupled formulation    (T => fill namsbc_cpl )
   nn_ice      = 2        !  =0 no ice boundary condition   ,
                          !  =1 use observed ice-cover      ,
                          !  =2 ice-model used                          ("key_lim3" or "key_lim2)
   nn_ico_cpl  = 0        !  ice-ocean coupling : =0 each nn_fsbc
                          !                      =1 stresses recomputed each ocean time step ("key_lim3" only)
                          !                      =2 combination of 0 and 1 cases             ("key_lim3" only)
   ln_dm2dc    = .false.  !  daily mean to diurnal cycle short wave (qsr)
   ln_rnf      = .true.   !  runoffs (T => fill namsbc_rnf)
   ln_ssr      = .true.   !  Sea Surface Restoring on T and/or S (T => fill namsbc_ssr)
   nn_fwb      = 0        !  FreshWater Budget: =0 unchecked                       ,
                          !                    =1 global mean of e-p-r set to zero at each time step
                          !                    =2 annual global mean of e-p-r set to zero
                          !                    =3 global emp set to zero and spread out over erp area
/

!-----------------------------------------------------------------------------------------------------------------------
&namsbc_core !   namsbc_core  CORE bulk formulea
!-----------------------------------------------------------------------------------------------------------------------
!       ! file name  ! frequency (hours) !  variable  ! time interpol. !  clim   ! 'yearly'/ ! weights            ! rotation !
!       !            !  (if <0  months)  !    name    !    (logical)   !  (T/F)  ! 'monthly' ! filename           ! pairing  !
sn_wndi ='drowned_u10_ERAinterim'    ,  3 , 'u10'      ,    .true.      , .false. , 'yearly'  , 'weight_bicubic_ERA', 'U1'
sn_wndj ='drowned_v10_ERAinterim'    ,  3 , 'v10'      ,    .true.      , .false. , 'yearly'  , 'weight_bicubic_ERA', 'V1'
sn_qsr  ='drowned_radsw_ERAinterim' , 24 , 'radsw'    ,    .false.     , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_qlw  ='drowned_radlw_ERAinterim' , 24 , 'radlw'    ,    .false.     , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_tair ='drowned_t2_ERAinterim'    ,  3 , 't2'       ,    .true.      , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_humi ='drowned_q2_ERAinterim'    ,  3 , 'q2'       ,    .true.      , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_prec ='drowned_precip_ERAinterim', 24 , 'precip'   ,    .true.      , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_snow ='drowned_snow_ERAinterim'  , 24 , 'snow'     ,    .true.      , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_tdif ='taudif'                   , 24 , 'taudif'   ,    .true.      , .false. , 'yearly'  , ''                  ,   ''
sn_ccov ='drowned_tcc_ERAinterim'   , 24 , 'tcc'      ,    .true.      , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_mslp ='ERAinterim_PRES_POG'      ,  3 , 'somslpre' ,    .true.      , .false. , 'yearly'  , 'weight_bilin_ERA'  ,   ''
sn_cosr ='COEFF_FLCOSSRD_POG_bisex' , 24 , 'coefsdsw' ,    .false.     , .true.  , 'yearly'  , 'weight_bilin_025'  ,   ''
sn_colw ='COEFF_FLCOSTRD_POG_bisex' , 24 , 'coefsdlw' ,    .false.     , .true.  , 'yearly'  , 'weight_bilin_025'  ,   ''
sn_copre='COEFF_FLCOPRE_POG'        , 24 , 'socoprec' ,    .false.     , .true.  , 'yearly'  , 'weight_bilin_025'  ,   ''
!
   cn_dir      = './'      !  root directory for the location of the bulk files
   ln_2m       = .true.    !  air temperature and humidity referenced at 2m (T) instead 10m (F)
   ln_taudif   = .false.   !  HF tau contribution: use "mean of stress module - module of the mean stress" data ?
   rn_pfac     = 1.        !  multiplicative factor for precipitation (total & snow)
!!
   ln_kata     = .false.    !  enhanced katabatic winds (T) or no (F).
   sn_kati     = 'katamask'         , -1 , 'katamaskx',    .false.     , .true.  ,  'yearly' , ''                 ,   ''
   sn_katj     = 'katamask'         , -1 , 'katamasky',    .false.     , .true.  ,  'yearly' , ''                 ,   ''
!!
   ln_read_snow   = .true.  ! Read snowfalls from a file (T) or estimated from surface air temperature (F)
   ln_read_mslp   = .false.   ! Read mean sea level pressure from a file (T) or assumed to be constant at 100800 Pa (F)
   ln_humi_rel    = .false.  ! Read relative humidity (T) or specific humidity (F)
```

```
   ln_corad_trop  = .false.     ! Correction of radiatives fluxes in the Tropics (T) or not (F)
   ln_corad_arc   = .true.      ! Correction of radiatives fluxes in the Arctic Ocean (T) or not (F)
   ln_corad_antar = .true.      ! Correction of radiatives fluxes in the Southern Ocean (T) or not (F)

/
```

Radiative flux and precipitation corrections

The radiative fluxes (both long wave and short wave) and precipitation exhibit unacceptable bias. Therefore a specific correction has been implemented by Garric (reference paper ?) in order to improve those fluxes and precipitation. For radiative fluxes, a correction factor based on the comparison between ERA-interim fluxes and satellite fluxes products (GEWEX) is computed. For precipitation, the correction uses large scale GPCP product. These corrections required some change in the code as described here. Basically, the idea is to apply a 2D scaling coefficient to the large scale features of the radiative fluxes and precipitation. Original fields are band-pass filtered to separate large scales and small scales, using a shapiro filter, applied 250 times during the period 1989-1991 and enhanced to 600 times during the period 1992-2007 (which reduced the performance rate of the model computing by 5%). The correction is applied to the large scale and then the small scale is added to produce the radiative fluxes and precipitation for the model. Finally we applied a scale factor to this radiative flux correction in Arctic and Southern Ocean (solar heat flux: 70% in the Arctic and 80% in the Southern Ocean; long wave heat flux: 110% in the Arctic and Southern Ocean). For precipitation, we only applied the correction between 30°S and 30°N, with a buffer zone between 30°N/S and 40°N/S. No correction is applied northward of 40°N and southward of 40°S.

Light penetration algorithm according to ocean color

In this simulation we use a non-standard parametrization of the penetration of the solar flux in the ocean, modulated by the chlorophyll concentration, deduced from satellite (SeaWIFS ocean color products) ocean color monthly climatology developed by [4]. In this solar radiation penetration formulation, visible light is split into three wavebands: blue (400-500nm), green (500-600nm), red (600-700nm).

```
!-----------------------------------------------------------------------------------------------------------------------
&namtra_qsr    !   penetrative solar radiation
!-----------------------------------------------------------------------------------------------------------------------
!              !  file name ! frequency (h) ! variable   ! time interpol. !  clim  ! 'yearly'  ! weights  ! rotation !
!              !            !(if <0  months)!   name     !    (logical)   !  (T F) ! 'monthly' ! filename ! pairing  !
   sn_chl      ='chlorophyl',        -1     , 'CHLA'     ,    .true.      , .true. , 'yearly'  , ''       , ''

   cn_dir      = './'      !  root directory for the location of the runoff files
   ln_traqsr   = .true.    !  Light penetration (T) or not (F)
   ln_qsr_rgb  = .true.    !  RGB (Red-Green-Blue) light penetration
   ln_qsr_2bd  = .false.   !  2 bands              light penetration
   ln_qsr_bio  = .false.   !  bio-model light penetration
   nn_chldta   =      0    !  RGB : Chl data (=1) or cst value (=0)
   rn_abs      =   0.58    !  RGB & 2 bands: fraction of light (rn_si1)
   rn_si0      =   0.35    !  RGB & 2 bands: shortess depth of extinction
   rn_si1      =   23.0    !  2 bands: longest depth of extinction
   rn_si2      =   62.0    !  3 bands: longest depth of extinction (for blue waveband & 0.01 mg/m2 Chl)
/
```

Diurnal Cycle on solar fluxes

In this run and contrary to ORCA025.L75-MJM95, there is no parametrization of the diurnal cycle on the solar flux. We don't implement it in order to respect the choice made in the K001 previous run.

River Run-off

For K001 and MAL95 simulations, the coastal and river run-off data is inferred from the file [2] runoff_coast1pt_ant3pt_isl20_obtaz_1m_ORCA12_correctAMZ_200610_lbclnk.nc. Contrary to ORCA025.L75-MJM95, there is no specific treatment at rivers mouths.

```
!-----------------------------------------------------------------------------------------------------------------------
&namsbc_rnf !   runoffs namelist surface boundary condition
!-----------------------------------------------------------------------------------------------------------------------
!        !     file name    ! frequency (h) ! variable ! time interpol. !  clim   ! 'yearly' ! weights  ! rotation !
!        !                  !(if <0  months)!   name   !    (logical)   !  (T F)  ! 'monthly'! filename ! pairing  !
   sn_rnf ='runoff_1m_nomask',        -1     ,'sorunoff',    .true.      , .true.  , 'yearly'  , ''       , ''
   sn_cnf ='runoff_1m_nomask',         0     ,'socoefr' ,    .false.     , .true.  , 'yearly'  , ''       , ''
!
   cn_dir       = './'      !  root directory for the location of the runoff files
   ln_rnf_emp   =   .false. !  runoffs included into precipitation field (T) or into a file (F)
   ln_rnf_mouth =   .false. !  specific treatment at rivers mouths
   rn_hrnf      =   10.e0   !  depth over which enhanced vertical mixing is used
   rn_avt_rnf   =   2.e-3   !  value of the additional vertical mixing coef. [m2/s]
   rn_rfact     =   1.e0    !  multiplicative factor for runoff
/
```

SSS restoring strategy

We used standard Sea Surface Salinity restoring toward Levitus, with a time scale of 60 days/10 meters (considered as rather strong). There is no SSS damping under sea-ice. A limitation is applied to the restoring term ($|Sobs - Smodel| \leq 0.5PSU$), to limit the damping in regions with large variations of the SSS, like in boundary currents or the NAC. Then we apply ERP bounding on this resulting SSS (limitation at 4 mm/day as it was the case in ORCA025.L75-MJM95)[3], which exactly corresponds to 4mm/day assuming 1 water $m^3 = 10^3 Kg$. There is no enhancement of the restoring term in the Mediterranean Sea like in ORCA025.L75-MJM95. In the next ORCA12 runs we have to decide which regional parametrization for salinity restoring to implement.

```
!-----------------------------------------------------------------------------------------------------------------------
&namsbc_ssr !   surface boundary condition : sea surface restoring
!-----------------------------------------------------------------------------------------------------------------------
!       !  file name ! frequency (hours) ! variable   ! time interpol. !  clim   ! 'yearly'  ! weights  ! rotation !
!       !            !  (if <0  months)  !   name     !    (logical)   !  (T F)  ! 'monthly' ! filename ! pairing  !
sn_sst   = 'sst_data' ,        24         ,  'sst'     ,     .false.    , .false. , 'yearly'  , ''       , ''
sn_sss   = 'sss_1m'   ,        -1         , 'vosaline' ,     .true.     , .true.  , 'yearly'  , ''       , ''

cn_dir   = './'      !  root directory for the location of the runoff files
nn_sstr  =     0     !  add a retroaction term in the surface heat       flux (=1) or not (=0)
nn_sssr  =     2     !  add a damping     term in the surface freshwater flux (/=0) or not (=0)
                     !                                          salt flux (=1) or volume flux (=2)
rn_dqdt  =   -40.    !  magnitude of the retroaction on temperature   [W/m2/K]
rn_deds  =   -166.67 !  magnitude of the damping on salinity   [mm/day/psu]
                     !      = 999  => use 2D-mask from sn_deds

sn_deds  = 'cdmp2D'  ,          0         ,  'cdmp2d'  ,    .false.     , .true.  , 'yearly'  , ''       , ''

 rn_sssr_ds  =  0.5    ! ABS(Max/Min) limit of salinity difference for damping term computation (=0 for no limitation)
 ln_sssr_bnd =  .true. ! flag to bound erp term (associated with nn_sssr=2)
 rn_sssr_bnd =  4.e0   ! ABS(Max/Min) value of the damping erp term [mm/day]
 nn_sssr_ice =    0    ! orig. DRAKKAR customization: chose action for under sea ice sss damping (formerly: nn_icedmp)
                       !         0 : no damping
                       !         1 : damping as in the ocean (D)
                       !        >1 : damping under ice x nn_icedmp
/
```

[2] provided by MERCATOR and Anne-Marie Tréguier

[3] Note that the Kiel run only use the limitation on absolute SSS, not the ERP bounding (*ln_sssr_bnd=.false.*). We applied this ERP bounding by error... And it seems to have an impact because some of the output fields have a *sowafldp* (surface water flux related to SSS damping) range between $-4.62963.10^{-5}$ and $4.62963.10^{-5} kg/m^2/S$

1.2.5 Lateral boundary condition

The lateral momentum boundary condition was set to 0.5 (partial slip condition), with respect to K001. Note that it exists a sensitivity test concerning this shlat boundary condition: ORCA12.L46-MAL950 run was performed during 3 years (1989-1991) but with a free slip condition (shlat=0). This (too ?) short 3-year experiment does not show any clear improvement in the Gulf Stream detachment.

```
!-----------------------------------------------------------
&namlbc        !   lateral momentum boundary condition
!-----------------------------------------------------------
   rn_shlat    =    0.5    !      shlat = 0 : free slip
                           !  0 < shlat < 2 : partial slip
                           !      shlat = 2 : no slip
                           !  2 < shlat     : strong slip
/
```

1.2.6 Tracer damping strategy

There is no 3D tracer damping at all (nowhere in the ocean). Particularly there is no 3D restoring in the Gulf of Cadiz, leading to poor Mediterranean Waters in the Atlantic.

1.3 Ice details

1.3.1 EVP rheology

The model used the LIM2 model (without the Elasto-Visco-Plastic rheology). The ice-ocean coupling is done every 6 model steps.

1.3.2 Thermodynamics

The standard LIM2 thermodynamics is used. The only change with respect to the standard code is the use of cloud cover files (synoptic) instead of a standard constant value for nebulosity. It has an impact on the net shortwave radiation which is not absorbed in the thin surface layer and penetrates inside the ice cover.

Note that the ice thickness for lateral accretion (*hiccrit*) is 0.6 in the Northern and Southern Hemisphere.

```
!-------------------------------------------------------------------------------------
&namicedyn     !   ice dynamic
!-------------------------------------------------------------------------------------
epsd        =   1.0e-20 !  tolerance parameter
alpha       =   0.5     !  coefficient for semi-implicit coriolis
dm          =   0.6e+03 !  diffusion constant for dynamics
nbiter      =   1       !  number of sub-time steps for relaxation
nbitdr      = 100       !  maximum number of iterations for relaxation
om          =   0.5     !  relaxation constant
resl        =   5.0e-05 !  maximum value for the residual of relaxation
cw          =   5.0e-03 !  drag coefficient for oceanic stress
angvg       =   0.0     !  turning angle for oceanic stress
pstar       =   1.5e+04 !  1st bulk-rheology parameter
c_rhg       =  20.0     !  2nd bulk-rhelogy parameter
etamn       =   0.0e+07 !  minimun value for viscosity
creepl      =   2.0e-08 !  creep limit
ecc         =   2.0     !  eccentricity of the elliptical yield curve
ahi0        = 350.e0    !  horizontal eddy diffusivity coefficient for sea-ice [m2/s]
nevp        = 360       !  number of iterations for subcycling
telast      = 3600      !  timescale for elastic waves
alphaevp    = 1.0       !  coefficient for the solution of int. stresses
/
```

```
!-----------------------------------------------------------------------------------------------
&namicethd     !   ice thermodynamic
!-----------------------------------------------------------------------------------------------
hmelt       = -0.15     !  maximum melting at the bottom
hiccrit     = 0.6 , 0.6 !  ice thickness for lateral accretion in the Northern (Southern) Hemisphere
hicmin      = 0.2       !  ice thickness corr. to max. energy stored in brine pocket
hiclim      = 0.05      !  minimum ice thickness
amax        = 0.999     !  maximum lead fraction
swiqst      = 1.        !  energy stored in brine pocket (=1) or not (=0)
sbeta       = 1.        !  numerical caracteritic of the scheme for diffusion in ice
                        !        Cranck-Nicholson (=0.5), implicit (=1), explicit (=0)
parlat      = 0.0       !  percentage of energy used for lateral ablation
hakspl      = 0.5       !  slope of distr. for Hakkinen-Mellor's lateral melting
hibspl      = 0.5       !  slope of distribution for Hibler's lateral melting
exld        = 2.0       !  exponent for leads-closure rate
hakdif      = 1.0       !  coefficient for diffusions of ice and snow
thth        = 0.2       !  threshold thickness for comp. of eq. thermal conductivity
hnzst       = 0.1       !  thickness of the surf. layer in temp. computation
parsub      = 1.0       !  switch for snow sublimation or not
alphs       = 1.0       !  coefficient for snow density when snow ice formation
/
```

2 Model configuration

2.1 Bathymetry

The bathymetry used for this run is a merge of etopo2 for the deep ocean and gebco1 for shallow areas (old bathymetry file - bathymeter_p083_05.nc - by error). The minimum depth in the model was set to 14.3 meters (3 vertical levels with partial step condition).

2.2 Horizontal grid

The horizontal grid is the standard ORCA12 tri-polar grid (4322 x 3059 grid points). The 1/12° resolution corresponds to the equator (10km). Resolution increases poleward: 5km at 60°, 3.5km at 75° (the grid size is scaled by the cosine of the latitude, except in the Arctic, of course).

2.3 Vertical grid

The vertical grid has 46 levels, with a resolution of 6m near the surface and 250m in the deep ocean.

2.4 Initial conditions

2.4.1 Ocean

The original K001 simulation ([5]) (does it exist a more complete or more recent reference ?) started from rest in 1978, with initial climatological temperatures and salinities. The used climatology was a merge of the Levitus 1998 climatology, patched with PHC2 for the Arctic regions and Medatlas for the Mediterranean Sea. The ORCA12.L46-MAL95 simulation is initialized from restart files provided by the Kiel group in 1989, January 1^{st}. This restart file was 46.8 GB (ocean) and 5.0 GB (ice) : we had to stripe it on 20 disks (with JADE lfs commands) to reduce the reading time.

2.4.2 Ice

The Kiel run (K001) used the ice standard initialisation from Levitus SST climatology, with following parameters:

- 3m (1m) sea-ice width in the north (south);
- 0.5m (0.1m) snow width in the north (south);
- 5% (10%) leads area in the north (south).

```
!-----------------------------------------------------------------------------------------------------
&namiceini     !   ice initialisation
!-----------------------------------------------------------------------------------------------------
ln_limini   = .false.   !  read the ice initial state in the file 'Ice_initialization.nc' (T) or not (F)
ttest       =  2.0      !  threshold water temperature for initial sea ice
hninn       =  0.5      !  initial snow thickness in the north
hginn       =  3.0      !  initial ice  thickness in the north
alinn       =  0.05     !  initial leads area     in the north
hnins       =  0.1      !  same  three parameter  in the south
hgins       =  1.0      !       "                  "     south
alins       =  0.1      !       "                  "     south
/
```

The ORCA12.L46-MAL95 simulation started from an ice restart file from this K001 simulation in 1989, January 1^{st}.

2.5 Miscellaneous

During the entire run performed at MEOM-LEGI (1989-2007) we used a time step of 360 sec. But the time step used at the beginning of the K001 run performed at IFM-Geomar (Kiel) was 72 sec for the first 5 days, and then increased progressively to 144 sec for days 6-15, 300 sec for days 16-20 and 360 sec after. Robert-Asselin filter parameter was increased to 0.2 for the first 10 days (K001) to avoid overshoots, and then reduced to the configuration default value 0.1. We kept this default value for the entire ORCA12.L46-MAL95 run over the period 1989-2007.

3 Run production

3.1 Integration and computing performance

The run started January, 1^{st}, 1989 (restart [4] from K001, which started January, 1^{st}, 1978) and ended December, 31^{st}, 2007, corresponding to the available ERA-interim forcing field. Note however that we don't compute 2008-2009 (whereas ERA-interim forcing field is available at this period), because the Kiel run (K001) ended in 2007. The run was performed at CINES HPC center in Montpellier, using 2032 cores of the SGI Altix ICE 8200 cluster (Jade). The domain decomposition used is 46 x 60 cores along x- and y- directions respectively for a total of 2032 computing core (land domain were eliminated). Each core computes 96 x 53 grid points. The placement strategy implemented (no "depopulated core condition" but "away-neighbour placement") allowed us to reach computing performance of 56 000 CPU hours per simulated year (28 elapsed hours per simulated year). The total CPU cost of this 19-year simulation is 1 091 162 CPU hours. More details about performance computing strategy can be found in [3] and on demand at

[4] To restart we had to stripe the 46.8GB (ocean) + 5.0GB (ice) restart files from K001 on 20 disks.

albanne.lecointre@legi.grenoble-inp.fr. We performed 6-month runs with a 15h00 walltime, with a restart file frequency of 6 months [5].

3.2 Model output

Model output is done as 5-days averages. Then monthly and annual means are computed in the post processing. The output size represents 1.9Tb per year (for 5-day + monthly and annual means). We also computed two climatologies over the periods 1998-2007 (the last 10 years) and 2003-2007 (for comparison with T321 Mercator run).

3.3 Journal of the run

A detailed journal of the run production is available on demand at albanne.lecointre@legi.grenoble-inp.fr.

4 Validation

The ORCA12.L46-MAL95 validation that is presented here is extracted from the monitoring of the experiment, available on demand on the Drakkar web site (contact bernard.barnier@legi.grenoble-inp.fr).

4.1 Mean state of the ocean (1998-2007)

We present here maps of the time mean of the major ocean variables (temperature, salinity, sea surface height, barotropic transport streamfunction and meridional overturning circulation).

[5] Finally, only 1-year restart files were archived.

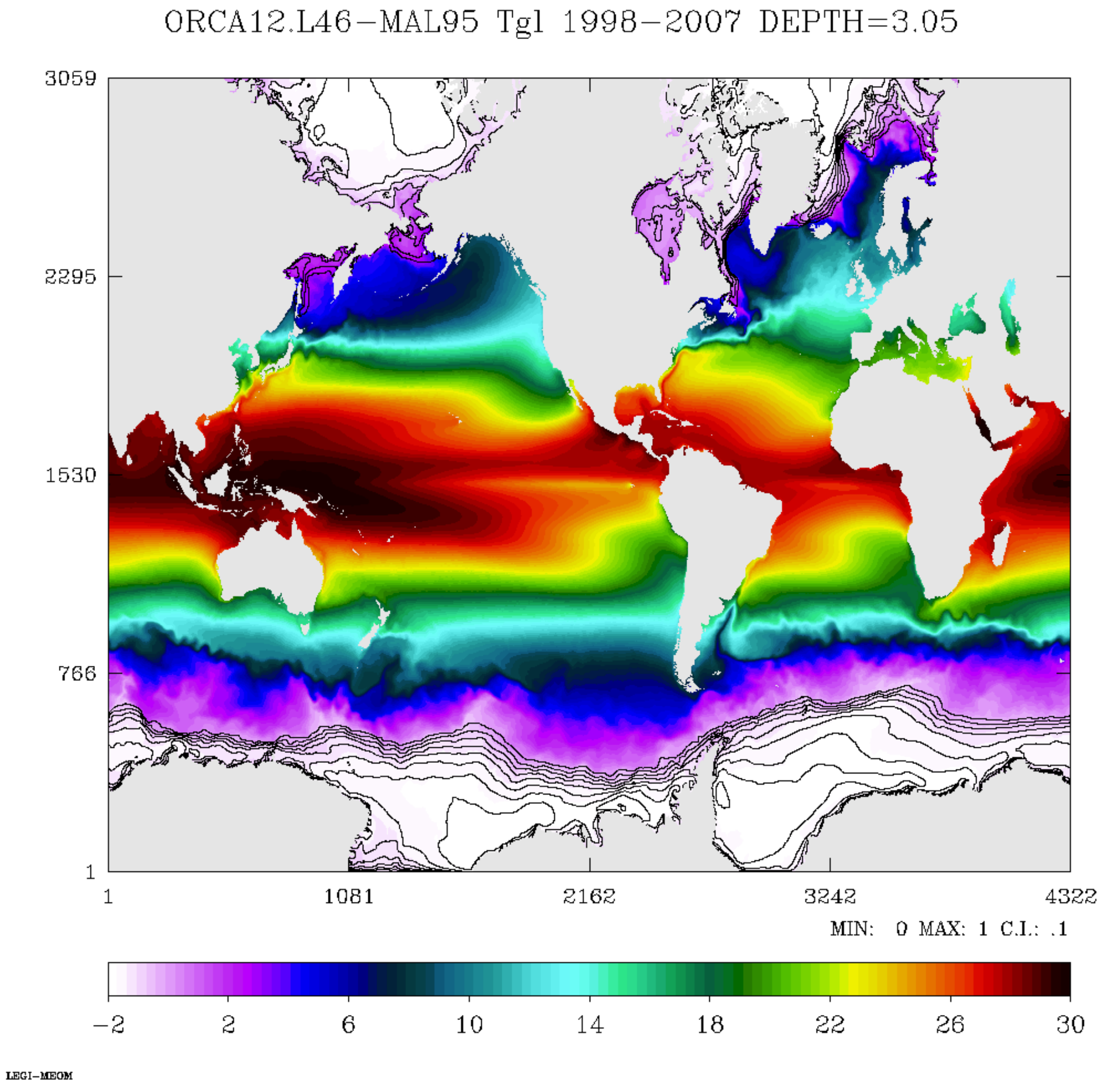

Figure 1: Mean Sea Surface Temperature over the period 1998-2007. Colours indicate the SST in °C, and contour lines indicate the sea ice thickness.

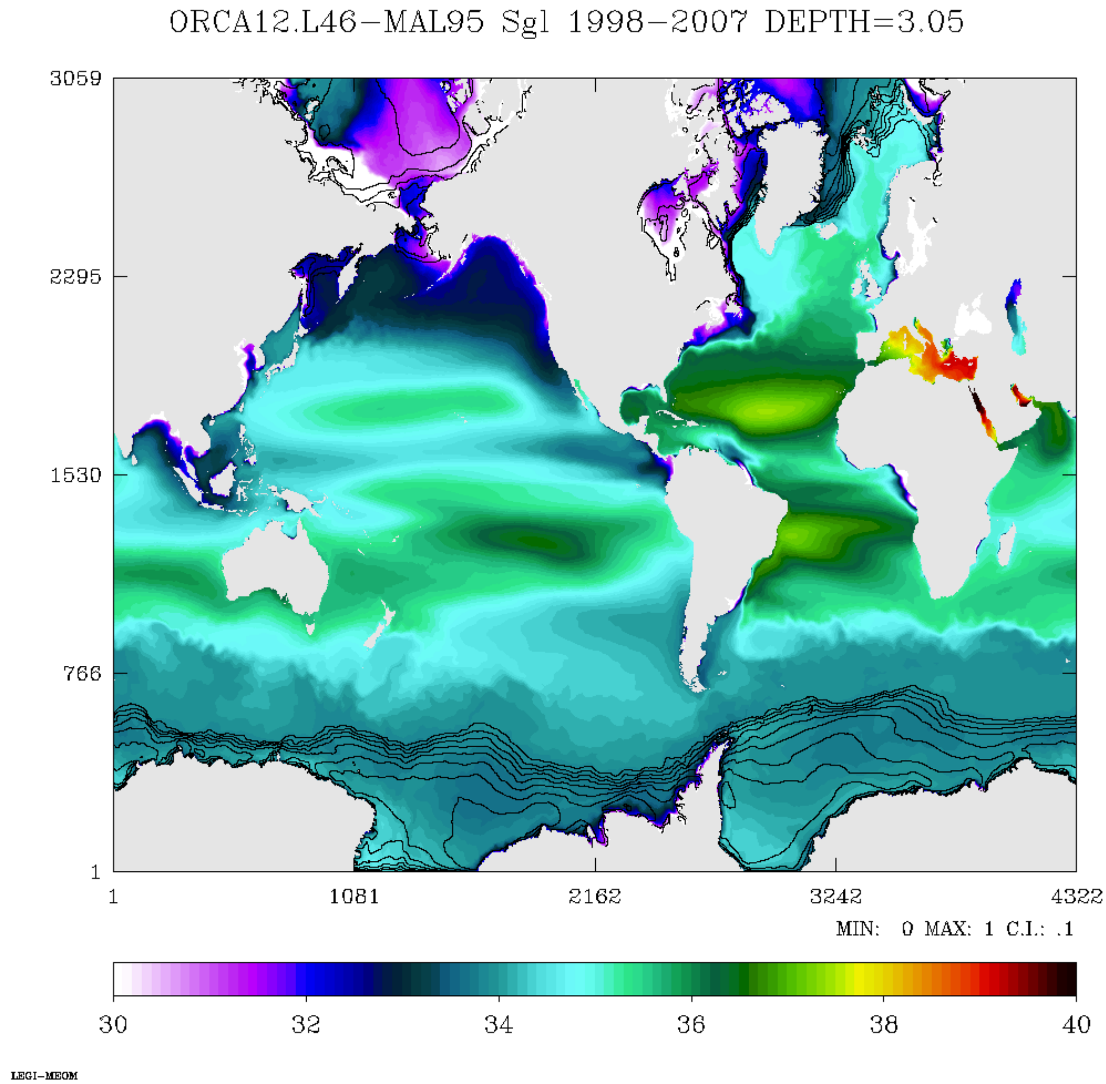

Figure 2: Mean Sea Surface Salinity over the period 1998-2007. Colours indicate the SSS, and contour lines indicate the sea ice thickness.

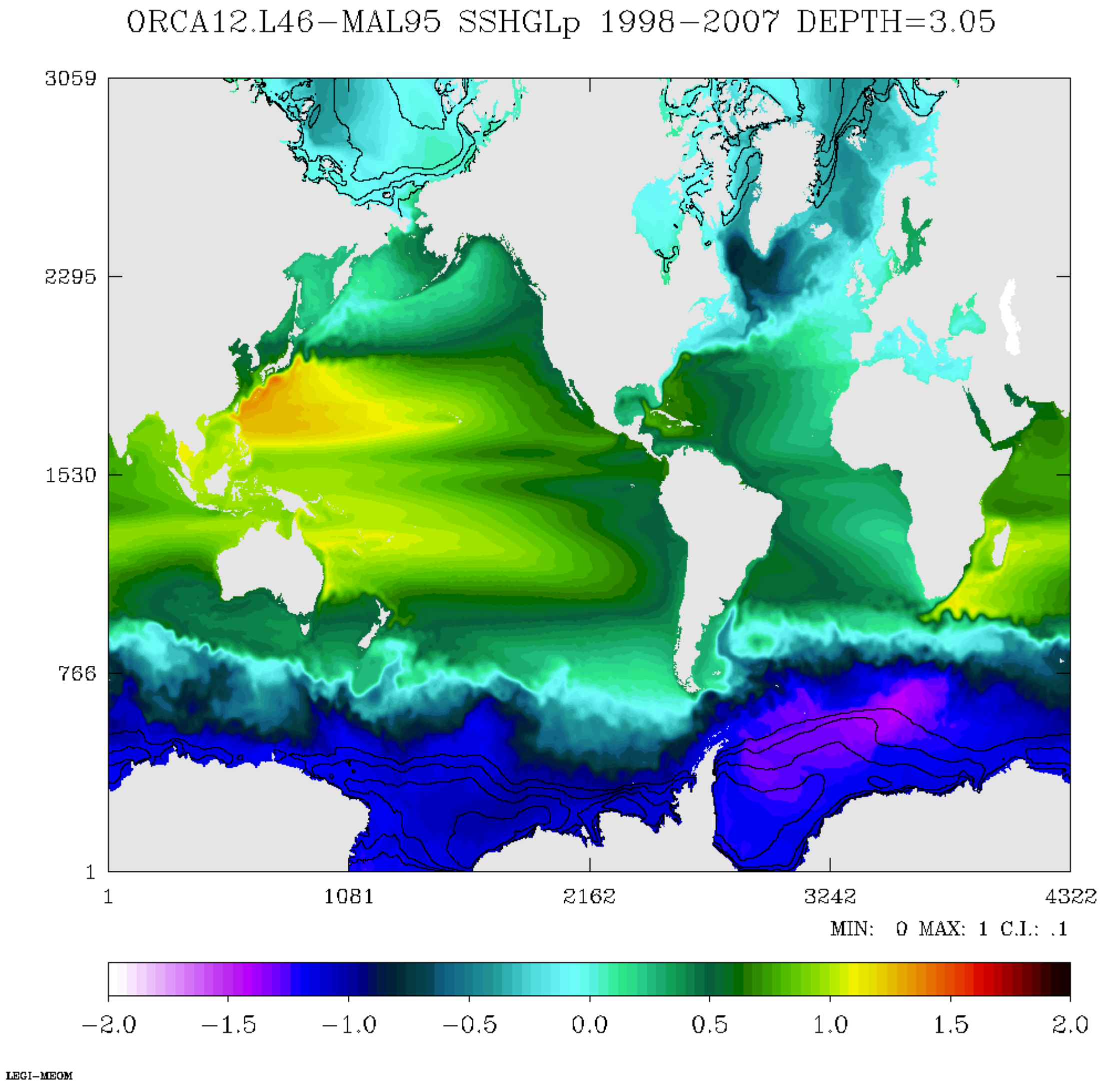

Figure 3: Mean Sea Surface Height over the period 1998-2007. Colours indicate the SSH in meters, and contour lines indicate the sea ice thickness.

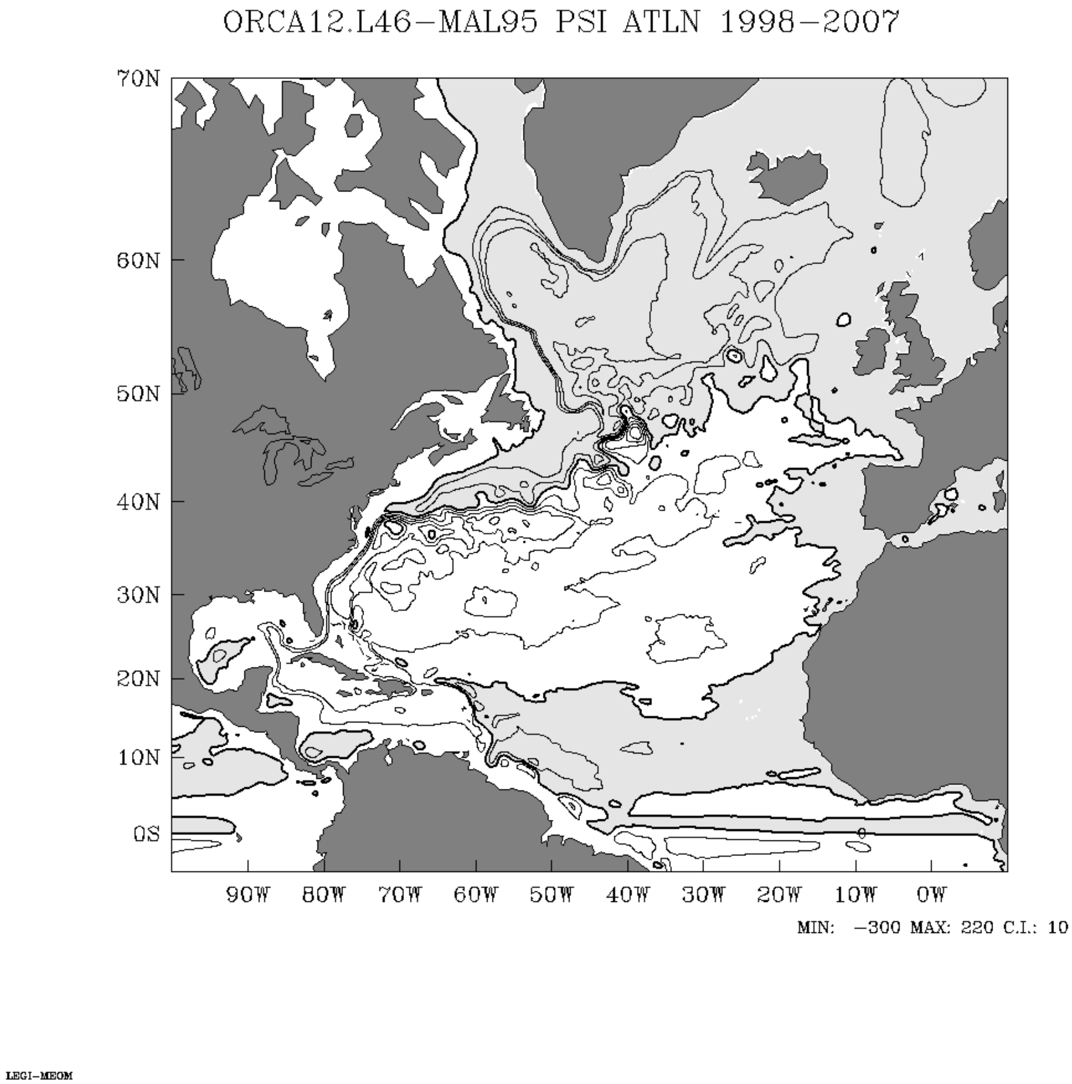

Figure 4: Mean Barotropic Streamfunction over the period 1998-2007. Contours by 10 Sv, negative values are shaded.

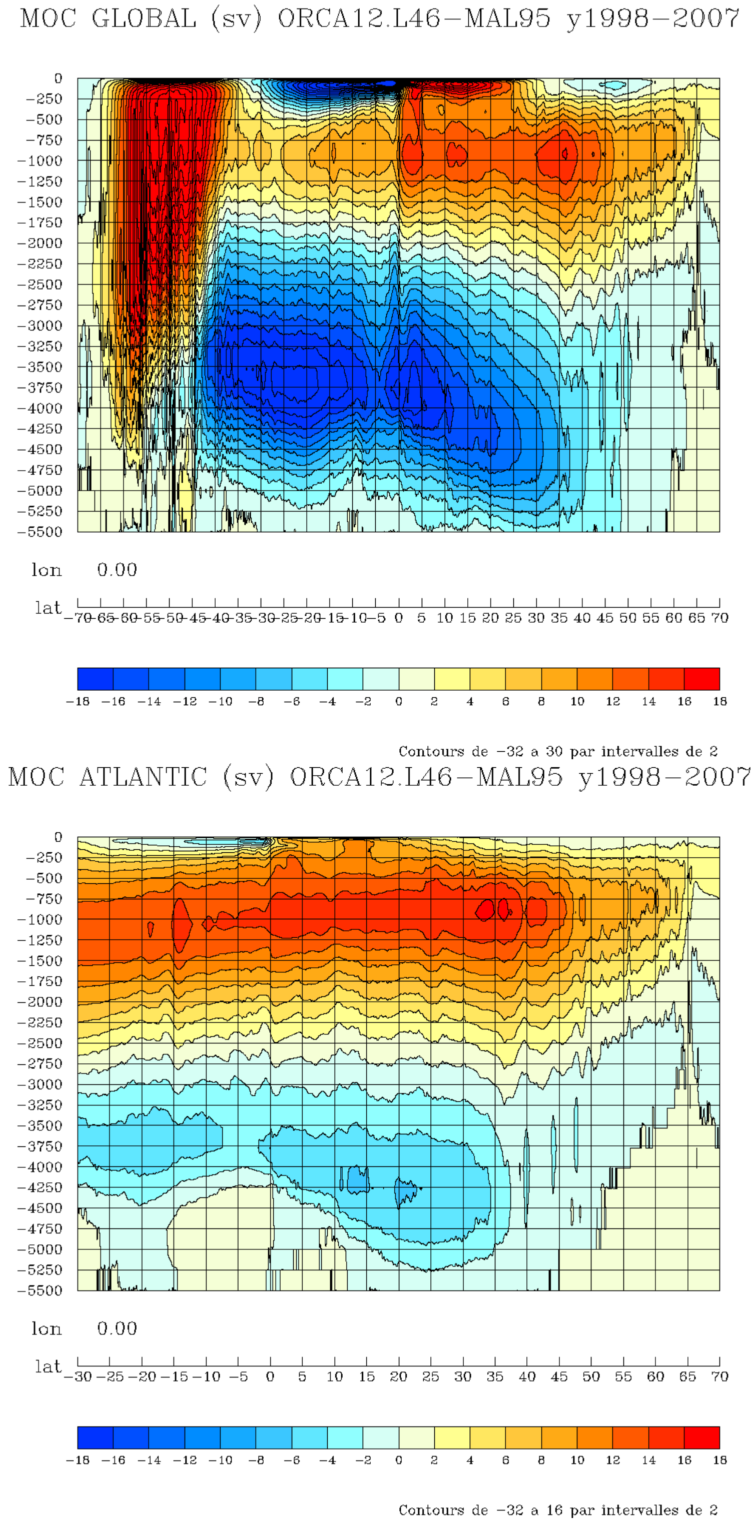

Figure 5: Mean Overturning over the period 1998-2007. Top: Global Ocean, bottom: Atlantic Ocean. Contours by 2 Sv.

4.2 Temperature and salinity CLASS1-1

The 10-year mean temperature difference with Levitus 2009 climatology at various depths (0m, 100m, 500m) is shown below.

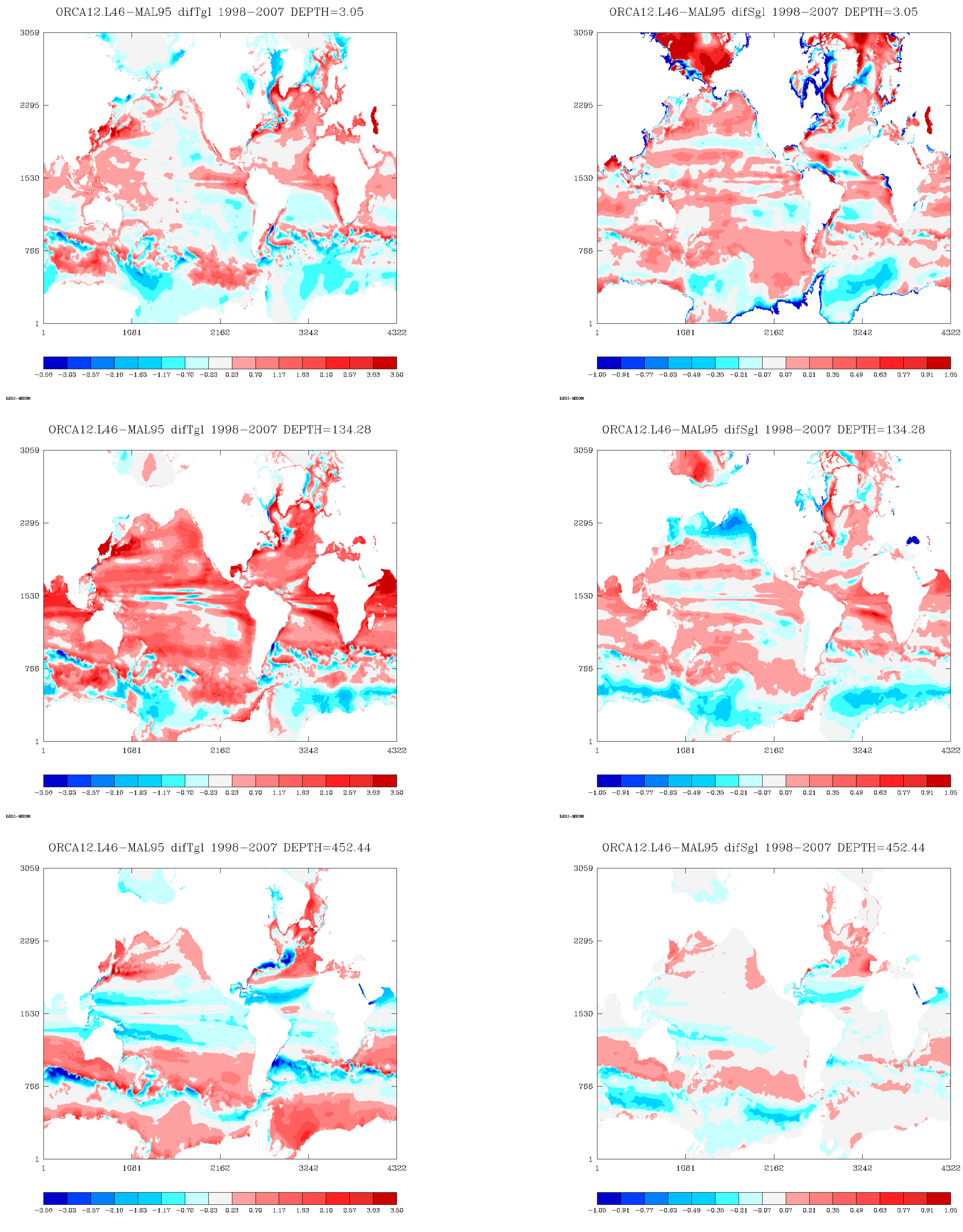

Figure 6: Difference between the 10-year mean temperature (left) and salinity (right) of the ORCA12.L46-MAL95 simulation with Levitus 2009 climatology at various depths (0m, 100m, 500m). Positive (negative) values indicate that the model solution is warmer or saltier (cooler or fresher) than the climatology.

4.3 Heat and Freshwater surface fluxes CLASS1-4

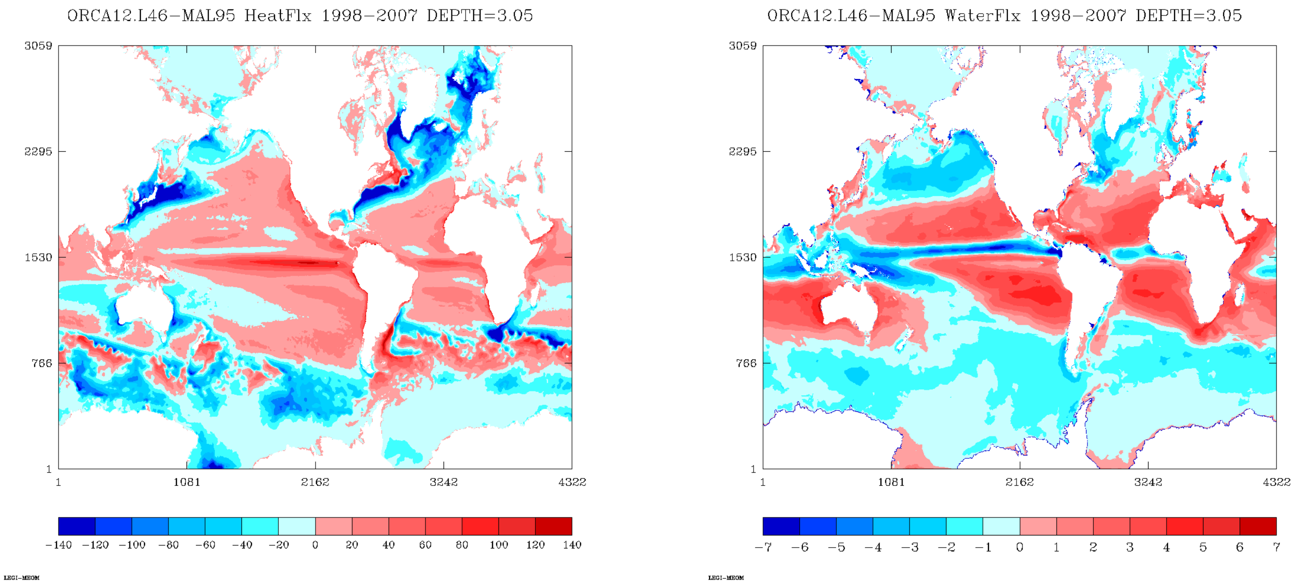

Figure 7: ORCA12.L46-MAL95 10-year mean net heat flux in W/m2 (left), and freshwater flux in mm/day (right).

4.4 Sea-Ice CLASS1-3

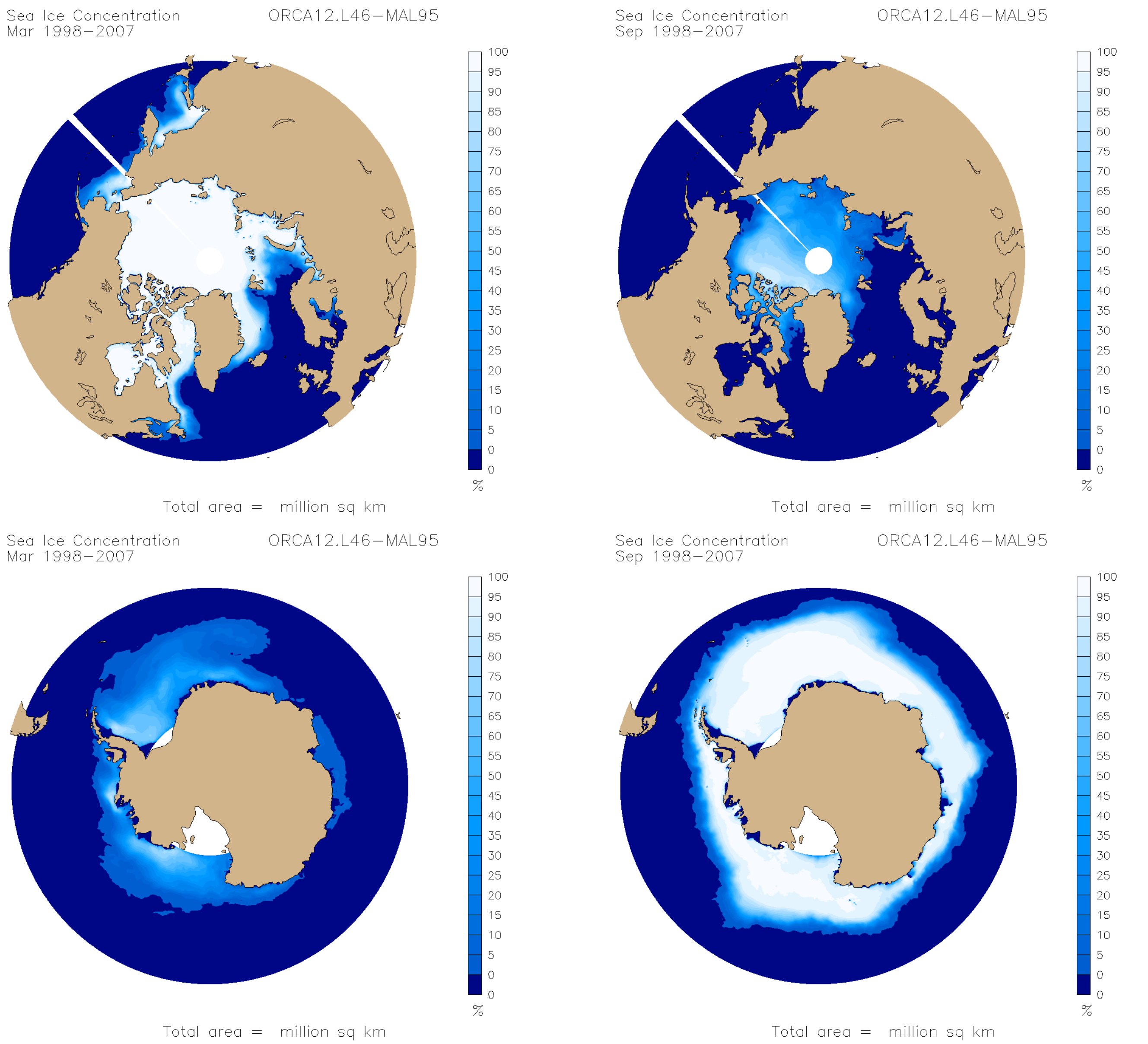

Figure 8: ORCA12.L46-MAL95 10-year mean sea-ice concentration in March (left) and September (right) in the Arctic (top) and in the Antarctic (bottom).

4.5 Variability

4.5.1 Temperature and salinity drifts

We show here the basin averaged drifts seen in temperature and salinity during the model integration.

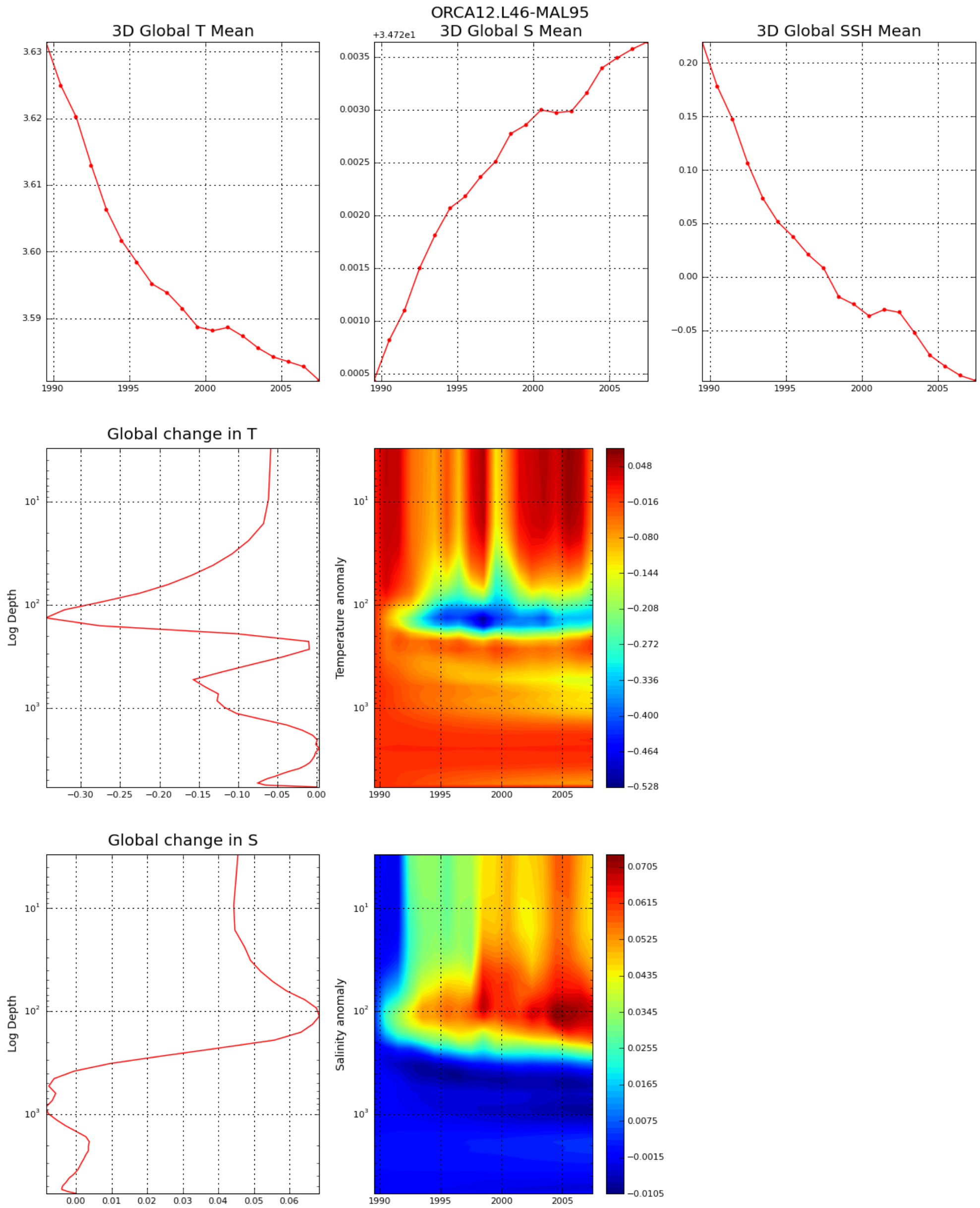

Figure 9: Top plots: Year-to-year variations of the world ocean average temperature and salinity over the integration period (1989-2007). Middle and bottom plots: Changes compared to initial condition in horizontally averaged temperature and salinity (vertical logarithmic depth range), left is the final minus initial profile, and right is the time evolution of the difference with initial condition.

4.5.2 Overturning and Transport

We show the variations during the model integration of two important climatic indexes which are the strenght of the overturning (i.e. the maximum) streamfunction in the North Atlantic, and the transport at Drake Passage.

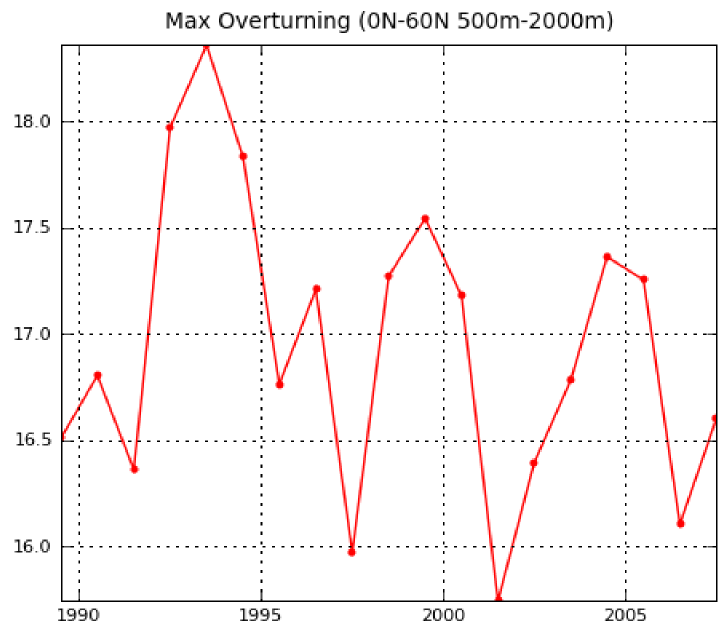

Figure 10: Variations of the annual mean maximum overturning (Sv) in the Atlantic Ocean over the integration period (1989-2007).

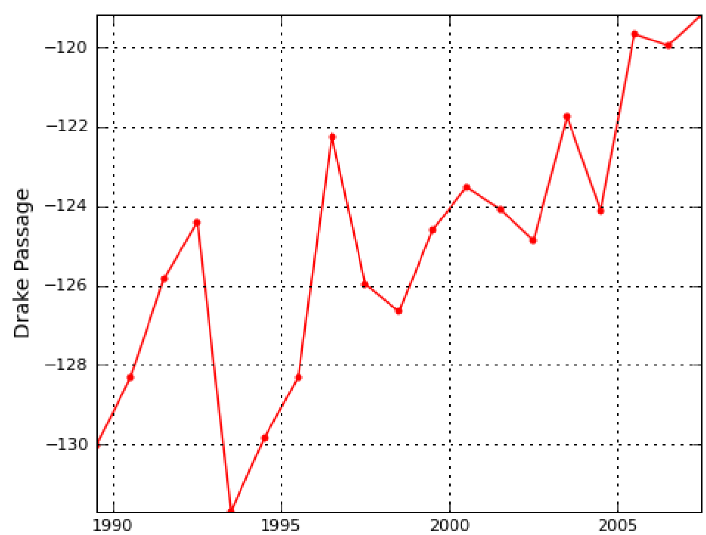

Figure 11: Variations of the annual mean transport (Sv) at the Drake Passage.

4.5.3 Sea-Ice variation CLASS1-3

We show here the variation of sea-ice characteristics and especially (CLASS1-3) the sea-ice concentration in summer 1996 (period of maximum sea-ice coverage) and in summer 2007 (period of minimum coverage). To be compared with satellite observations.

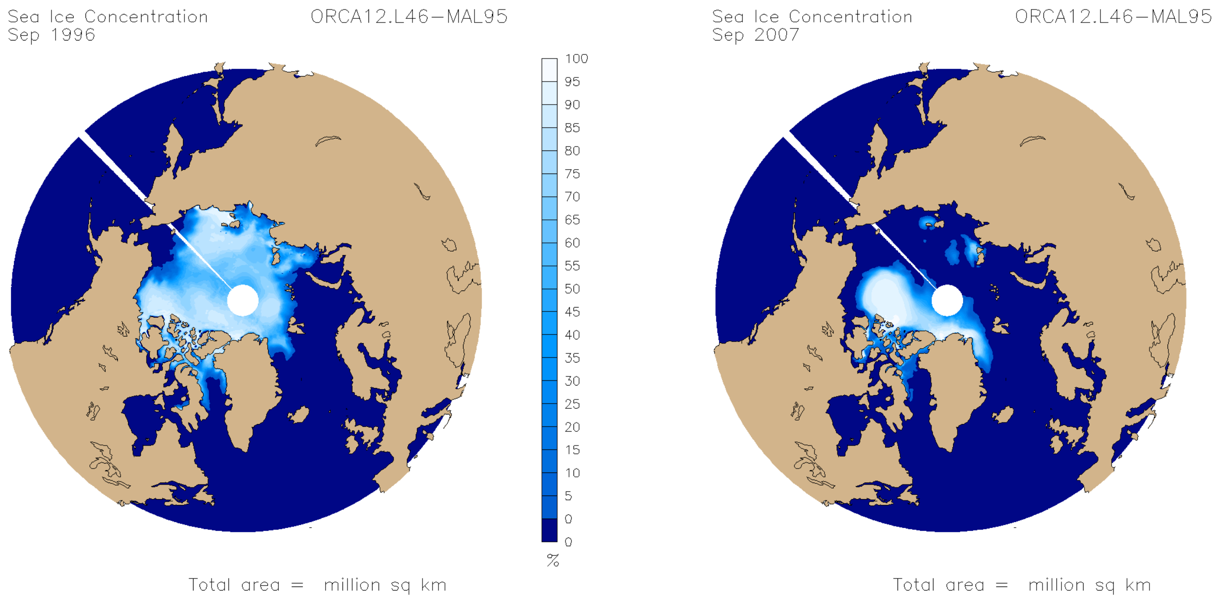

Figure 12: Sea-Ice Concentration (%) in the Arctic in September in 1996 (left) and in 2007 (right).

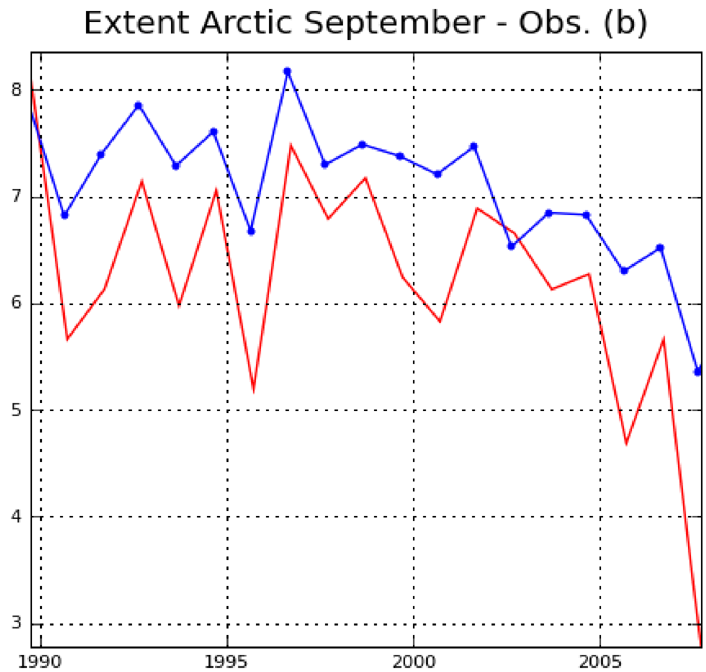

Figure 13: Sea-Ice Extent in September in the Arctic during the integration period (1989-2007). Blue curve is the model results and red curve is obtained from satellite observation. Annual means are centered on the middle of the year.

4.6 El Nino

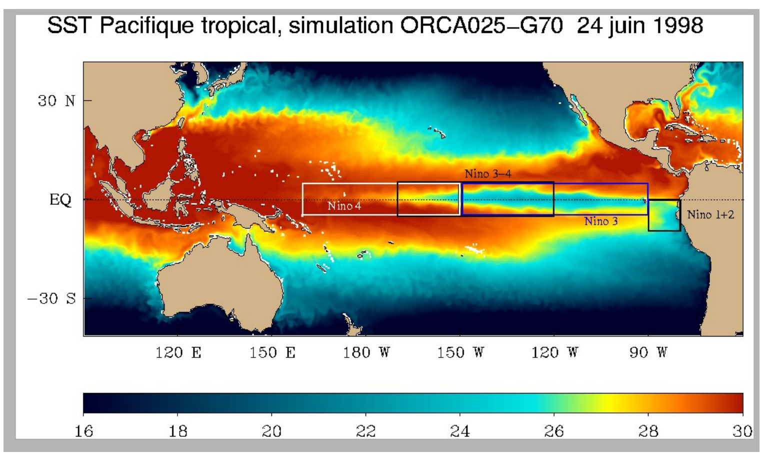

Figure 14: Definition of the Nino boxes.

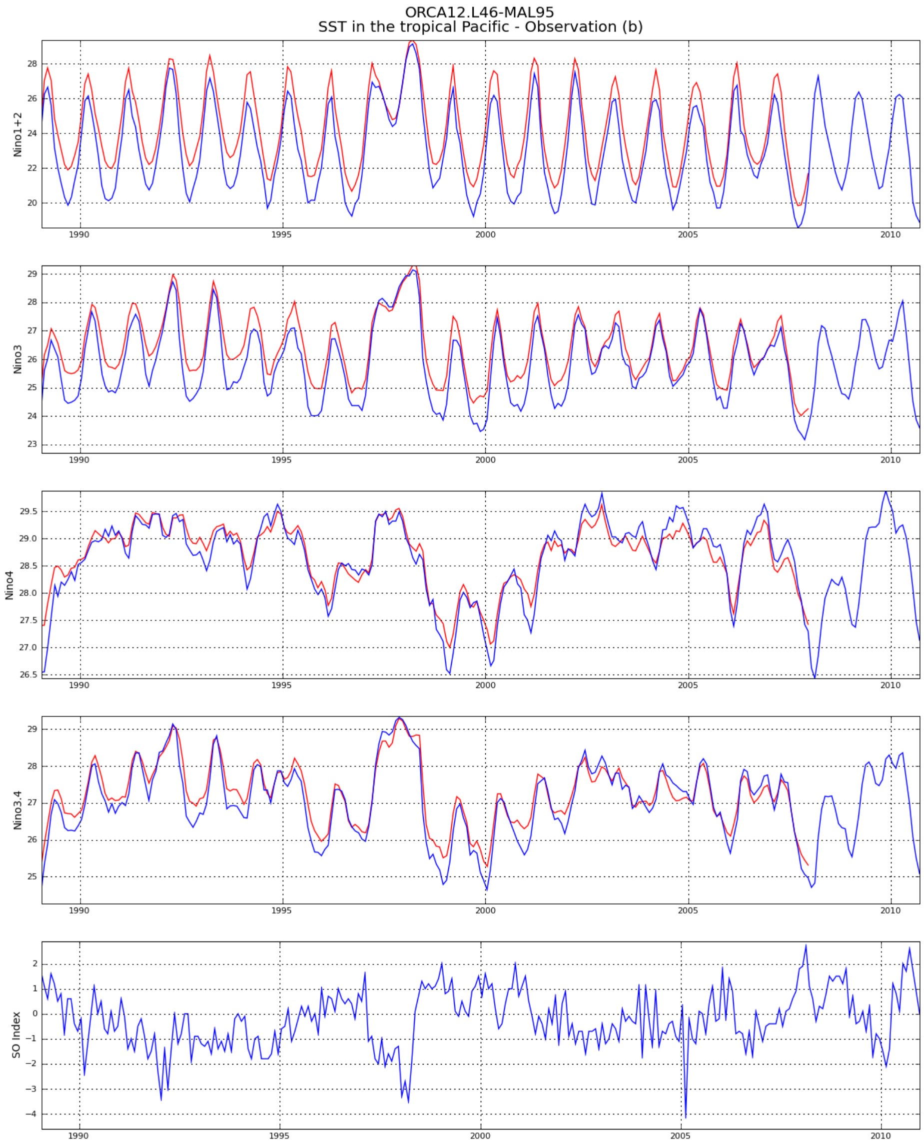

Figure 15: Monthly mean variations of the averaged temperature in el Nino boxes. Model is in black and observations (TOA array) are in green. Bottom plot is the Southern Oscillation index (monthly fluctuations in the air pressure difference between Tahiti and Darwin: sustained negative values of the SOI often indicate El Nino episodes).

Acknowledgement

This simulation has been performed on Jade supercomputer (CINES) with CPU hours allocated by GENCI (Grant GENCI X2011XXXXXXX).

References

[1] A. Beckmann and R. Döscher. A method for improved representation of dense water spreading over topography in geopotential-coordinate models.

[2] G. Hervieux. *Etude numérique des interactions courant-topographie: applications au gyre subpolaire, aux seuils de Gibraltar et des mers nordiques.* PhD thesis, Université J. Fourier, Grenoble, 2007.

[3] A. Lecointre, J.-M. Molines, and N. Audiffren. Tests de performance d'un modèle océanographique haute résolution sur le supercalculateur parallèle JADE (GENCI-CINES). Poster (a more detailed technical report is in preparation), HPC GENCI, May 19th, Paris, 2011.

[4] M. Lengaigne, C. Menkes, O. Aumont, T. Gorgues, L. Bopp, J.-M. André, and G. Madec. Bio-physical feedbacks on the tropical pacific climate in a coupled general circulation model.

[5] M. Scheinert, A. Biastoch, and C.W. Böning. The Global Ocean Model NEMO-ORCA12: Documentation of the Kiel DRAKKAR Experiment Setup. Technical report, IFM-Geomar, Kiel, Germany, 2010.