Definition of the interannual experiments ORCA12.L75-MAL83 (1978-1982) and ORCA12.L46-MAL83/84/85 (1978-1982 and 1978-1992)

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Introduction

This report describes in details the ORCA12.L75-MAL83 and ORCA12.L46-MAL83/84/85 simulations performed in the frame of the DRAKKAR project and computed at MEOM (LEGI, CNRS). The mesh is an ORCA grid 1/12° at equator, with partial-steps, 75 and 46 levels Drakkar type. These simulations are sensitivity experiments around ORCA0083.L75-N01 simulation performed at NOCS (Andrew COWARD, Southampton). ORCA12.L75-MAL83 is exactly the same simulation as ORCA0083.L75-N01 excepted that we don't apply the non-linear free surface. ORCA12.L46-MAL83/84/85 are sensitivity experiments (vertical resolution and momentum advection scheme) around ORCA12.L75-MAL83 simulation. The main purpose of this set of experiments was to understand why the Gulf Stream detachment seems to be realistic in ORCA0083.L75-N01 simulation, by removing one after each other some of its features (non-linear free surface, 75-level vertical resolution).

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

These experiments were performed with version 3.2.2 of NEMO. CPP keys used for compilation are:

CPP key name	Action:
key_orca_r12_l75 or key_orca_r12	ORCA12 horizontal grid with 75 or 46 vertical levels
key_traldf_c2d	2D lateral diffusion for tracers (depends on dx)
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_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

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. In this version and as for ORCA12.L46-MAL95/950 simulations ([4]), 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.

Compared to ORCA12.L46-MAL95/950 simulations, the vertical eddy viscosity and diffusivity terms are reduced of 20%, the enhanced mixing is applied only on tracer (not on momentum), and there is no horizontal shape for avtb[1].

```
!-----------------------------------------------------------------------------------------------
&namzdf        !   vertical physics
!-----------------------------------------------------------------------------------------------
   rn_avm0     =   1.0e-4  !  vertical eddy viscosity   [m2/s]          (background Kz if not "key_zdfcst")
   rn_avt0     =   1.0e-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    =    0      !  horizontal shape for avtb (=1) or not (=0)
   ln_zdfevd   = .true.    !  convection: enhanced vertical diffusion (T) or not (F)
   nn_evdm     =   0       !  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      =    0           !  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    = 60.0   ! coef. of the surface input of tke
rn_ebbice = 3.75   ! coef. of the surface input of tke under ice
```

[1] no horizontal variability of background (vertical Kz) contrary to ORCA025 simulations whose avtb linearly decreases in the equatorial band to improve equatorial undercurrent (5°S-5°N: avtb=avt0/10, and linear decrease/increase between 15°S-5°S / 5°N-15°N)

```
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   = 0.0001 ! 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
/
```

In order to try to solve the problem of blow-up when starting the simulations (see section 4 for further details), we slightly modified the interior buoyancy length scale minimum value (*rn_lmin*) in the different simulations[2]. The next table resumes its value for the L75-MAL83 and L46-MAL83/84/85 simulations over their respective period of integration.

Period of the run	ORCA12.L75-MAL83	ORCA12.L46-MAL83/84/85
J1: y1978m01d01	10^{-4}	10^{-4}
J2-J10: y1978m01d02-10	10^{-3}	10^{-4}
J11-end: y1978m01d11-end	10^{-4}	10^{-4}

1.2.2 Horizontal physics

Tracers

We use a laplacian isopycnal diffusivity for tracers. The diffusivity is proportional 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")
/
```

[2]but we don't think it has any impact on the model solution (and on our blow-up problem...)

Momentum

We use a bi-harmonic viscosity for the lateral dissipation[3]. 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)
/
```

In 75-level MAL83 simulation and in 46-level MAL83 and MAL84 simulations we use the standard vector form for the momentum advection scheme, with an energy and enstrophy conserving scheme. In 46-level MAL85 simulation we use a flux form for the evaluation of the momentum advection term (suggestion from J. Jouanno and G. Madec). The advection scheme is a 2^{nd} order centered finite difference scheme (*cen2*), always energy and enstrophy conserving.

- L75-MAL83 and L46-MAL83/84

```
!-----------------------------------------------------------------------
&namdyn_adv    !   formulation of the momentum advection
!-----------------------------------------------------------------------
   ln_dynadv_vec = .true.  !  vector form (T) or flux form (F)
   ln_dynadv_cen2= .false. !  flux form - 2nd order centered scheme
   ln_dynadv_ubs = .false. !  flux form - 3rd order UBS      scheme
/
!-----------------------------------------------------------------------
&namdyn_vor    !   option of physics/algorithm (not control by CPP keys)
!-----------------------------------------------------------------------
   ln_dynvor_ene = .false. !  enstrophy conserving scheme
   ln_dynvor_ens = .false. !  energy conserving scheme
   ln_dynvor_mix = .false. !  mixed scheme
   ln_dynvor_een = .true.  !  energy & enstrophy scheme
/
```

- L46-MAL85

```
!-----------------------------------------------------------------------
&namdyn_adv    !   formulation of the momentum advection
!-----------------------------------------------------------------------
   ln_dynadv_vec = .false.  !  vector form (T) or flux form (F)
   ln_dynadv_cen2= .true. !  flux form - 2nd order centered scheme
   ln_dynadv_ubs = .false. !  flux form - 3rd order UBS      scheme
/
!-----------------------------------------------------------------------
&namdyn_vor    !   option of physics/algorithm (not control by CPP keys)
!-----------------------------------------------------------------------
   ln_dynvor_ene = .false. !  enstrophy conserving scheme
   ln_dynvor_ens = .false. !  energy conserving scheme
   ln_dynvor_mix = .false. !  mixed scheme
   ln_dynvor_een = .true.  !  energy & enstrophy scheme
/
```

[3]except during the first 5-days of the simulations, see the section 4 dedicated to starting strategy for more details.

1.2.3 Bottom Boundary Layer

We used bottom boundary layer without any supplementary parametrizations:

- no diffusive BBL parametrization for tracer (contrary to ORCA12.L46-MAL95/950);
- no advective BBL parametrization for tracer;
- no advective BBL parametrization for momentum.

```
!-----------------------------------------------------------------------------------------
&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]
/
```

1.2.4 Surface boundary conditions

The surface boundary conditions are prescribed to the model using the CORE bulk formulation. As ORCA0083.L75-N01 simulation performed by NOCS group, our set of simulations were forced by DFS4.1 ([2]). The data set includes 4 turbulent variables (u10, v10, t2, q2) given every 6 hours, 2 daily radiative fluxes variables (swdn, lwdn) ad 2 monthly water flux variables (total precipitations, snow). Contrary to ORCA12.L46-MAL95/950, the turbulent variables (u10, v10, t2, q2), given every 6 hours, are not interpolated in time[4]. The high frequency fluctuation of wind stress (*taudif*) are absent from DFS and thus are not used. Contrary to ORCA12.L46-MAL95/950 simulations, we don't apply any correction on radiative fluxes and precipitations.

The global freshwater budget is checked (as in ORCA0083.L75-N01 simulation): emp is set to zero and spread out over erp area.

```
!-----------------------------------------------------------------------------------------------------
&namsbc        !   Surface Boundary Condition (surface module)
!-----------------------------------------------------------------------------------------------------
   nn_fsbc     = 1         !  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      = .false.   !  runoffs (T => fill namsbc_rnf)
   ln_ssr      = .true.    !  Sea Surface Restoring on T and/or S (T => fill namsbc_ssr)
   nn_fwb      = 3         !  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
/
```

[4] The effect is clearly visible on the number of solver iterations per step: it decreases from 600 iterations/step at the beginning of a 6-hour period to 300 iterations/step at the end of a 6-hour period, just before the following turbulent variables forcing.

```
!-----------------------------------------------------------------------------------------------------------------------
&namsbc_core !   namsbc_core  CORE bulk formulea
!-----------------------------------------------------------------------------------------------------------------------
!           !   file name  ! frequency (h) ! variable !time interp.! clim  ! 'yearly'/ ! weights        ! rotation !
!           !              !  (if <0 mont) !   name   ! (logical)  ! (T/F) ! 'monthly' ! filename       ! pairing  !
sn_wndi    = 'drowned_u10_DFS4.1'   ,  6  , 'u10'    ,    .false.   ,.false., 'yearly'  ,'weight_bicubic_ERA.nc','Ume'
sn_wndj    = 'drowned_v10_DFS4.1'   ,  6  , 'v10'    ,    .false.   ,.false., 'yearly'  ,'weight_bicubic_ERA.nc','Vme'
sn_qsr     = 'drowned_swdn_DFS4.1'  , 24  , 'swdn'   ,    .false.   ,.false., 'yearly'  ,'weight_bilin_NCAR.nc' ,''
sn_qlw     = 'drowned_lwdn_DFS4.1'  , 24  , 'lwdn'   ,    .false.   ,.false., 'yearly'  ,'weight_bilin_NCAR.nc' ,''
sn_tair    = 'drowned_t2_DFS4.1'    ,  6  , 't2'     ,    .false.   ,.false., 'yearly'  ,'weight_bilin_ERA.nc'  ,''
sn_humi    = 'drowned_q2_DFS4.1'    ,  6  , 'q2'     ,    .false.   ,.false., 'yearly'  ,'weight_bilin_ERA.nc'  ,''
sn_prec    = 'drowned_precip_DFS4.1', -1  , 'precip' ,    .true.    ,.false., 'yearly'  ,'weight_bilin_NCAR.nc' ,''
sn_snow    = 'drowned_snow_DFS4.1'  , -1  , 'snow'   ,    .true.    ,.false., 'yearly'  ,'weight_bilin_NCAR.nc' ,''
sn_tdif    = 'drowned_taudif_DFS4.1', 24  , 'taudif' ,    .true.    ,.false., 'yearly'  ,''                     ,''
!
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_abswind = .false.    ! use relative wind (false) or absolute wind (true) for the ocean stress
ln_abswind_ice = .false. ! use relative wind (false) or absolute wind (true) for the ice stress
/
```

Light penetration algorithm according to ocean color

In these simulations we use a standard parametrization of the penetration of the solar flux in the ocean. This scheme includes 2 wave bands of solar radiation penetration.

```
!-----------------------------------------------------------------------------------------------------------------------
&namtra_qsr !   penetrative solar radiation
!-----------------------------------------------------------------------------------------------------------------------
!          !   file name ! frequency (hours) ! 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 = .false.   !  RGB (Red-Green-Blue) light penetration
ln_qsr_2bd = .true.    !  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

There is no parametrization of the diurnal cycle on the solar flux (*ln_ dm2dc=.false.*), in 46-level and 75-level simulations (even with a 1m surface layer). We don't implement it in order to respect the choice made in the ORCA0083.L75-N01 reference simulation.

River Run-off

There is no run-off in our set of simulations (*ln_ rnf=.false.*), in order to respect the choice made in the ORCA0083.L75-N01 reference simulation.

SSS restoring strategy

We used standard Sea Surface Salinity restoring toward Levitus, with a time scale of 300 days/10 meters. The SSS restoring is weaker than in ORCA12.L46-MAL95/950 simulations (60 days/10 meters). There is no SSS damping under sea-ice. We use ERP bounding: a limitation at 4mm/day (like in ORCA025.L75-MJM95) is applied to the restoring term. Contrary to ORCA025.L75-MJM95, there is no enhancement of the restoring term in the Mediterranean Sea.

```
!-----------------------------------------------------------------------------------------------------------------------
&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     =   -33.333 !  magnitude of the damping on salinity   [mm/day/psu]
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]
! Drakkar customization
ln_sssr_flt =   .false. !  flag to filter sss for sss restoring
nn_shap_iter=   100     !  number of shapiro iterations for sss filtering

ln_sssr_msk =   .false. !  flag to use distance to coast to weight SSS restoring
sn_coast    = 'distcoast',     0             , 'Tcoast' ,  .false.       ,.true. , 'yearly'  , ''       , ''
rn_dist     =  150.     !  Decaying length scale (km) for SSS retoring fading near the coast
/
```

1.2.5 Lateral boundary condition

With respect to ORCA0083-N01, the lateral momentum boundary condition was set to 0 (free slip condition), except in Mediterranean Sea and Indonesian Through Flow. A 2D file from Andrew Coward for shlat conditions (*shlat2d_ORCA12grid_fev09.nc*) indicates that the shlat coefficient is 2 in Mediterranean Sea and Indonesian Through Flow, and 0 elsewhere (fig. 1). It gradually decreases from 2 to 0 at the buffer zone.

```
!-----------------------------------------------------------
&namlbc        !   lateral momentum boundary condition
!-----------------------------------------------------------
   rn_shlat    =    0.0    !      shlat = 0 : free slip
                           !  0 < shlat < 2 : partial slip
                           !      shlat = 2 : no slip
                           !  2 < shlat     : strong slip
   ln_shlat2d = .true.
/
```

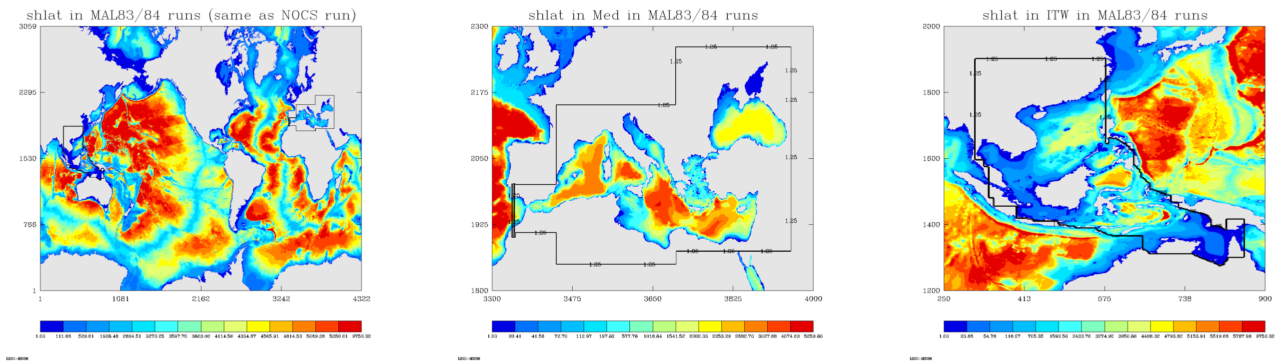


Figure 1: Bathymetry in ORCA12.L46/75-MAL83/84/85 simulations. Boxes (in Med waters + ITF) indicate the zone where shlat is set to 2 instead of 0.

1.2.6 Tracer damping strategy

There is no 3D tracer damping at all (nowhere in the ocean).

1.3 Ice details

The model used the LIM2 model (without the Elasto-Visco-Plastic rheology). The ice-ocean coupling is done at each model step. The frequency of sea-ice model call is thus 6 times higher than in ORCA12.L46-MAL95/950. The standard LIM2 thermodynamics is used.

```
!-----------------------------------------------------------------------------------------
&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       =   1.0e+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        = 200.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 , 0.3 !  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 these simulations (*ORCA12_bathymeter_p083_05_nocasp_gib.nc*) is a merge of etopo2 for the deep ocean and gebco1 for shallow areas. It is based on the ORCA0083.L75-N01 bathymetry file (*bathymeter_p083_05.nc*), but it was tuned around Gibraltar Strait (according to NATL12-BAMT20) and Caspian Sea was removed.

The minimum depth in the model was set to 13.3 meters in ORCA12.L75-MAL83 (10 vertical levels with partial step condition) and 14.3 meters in ORCA12.L46-MAL84/85 (3 vertical levels with partial step condition[5]). In ORCA12.L46-MAL83, the minimum depth was set to 88.7 meters by error: the limitation at 10 vertical levels (from 75-level configuration) was hard-coded in the *domzgr.F90* routine and we forgot to replace it by 3 vertical levels (for 46-level configuration).

```
domzgr.F90: zmin = gdepw_0(4)    ! minimum depth = 3 levels
domzgr.F90: !zmin = gdepw_0(11)  ! minimum depth = 10 levels (75 level case)
```

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).

2.3 Vertical grid

For ORCA12.L75-MAL83, the vertical grid has 75 levels, with a resolution of 1m near the surface and 200m in the deep ocean. For ORCA12.L46-MAL84/85, the vertical grid has 46 levels, with a resolution of 6m near the surface and 250m in the deep ocean. Figure 2.3 shows the level depths in 46-level and 75-level configurations, compared to other existing vertical resolution (50-level and 64-level).

[5] 4 w-level=3 t-level of the model whose third has a minimum depth of 20% (partial step) : e3t(1)+e3t(2)+0.2*e3t(3)

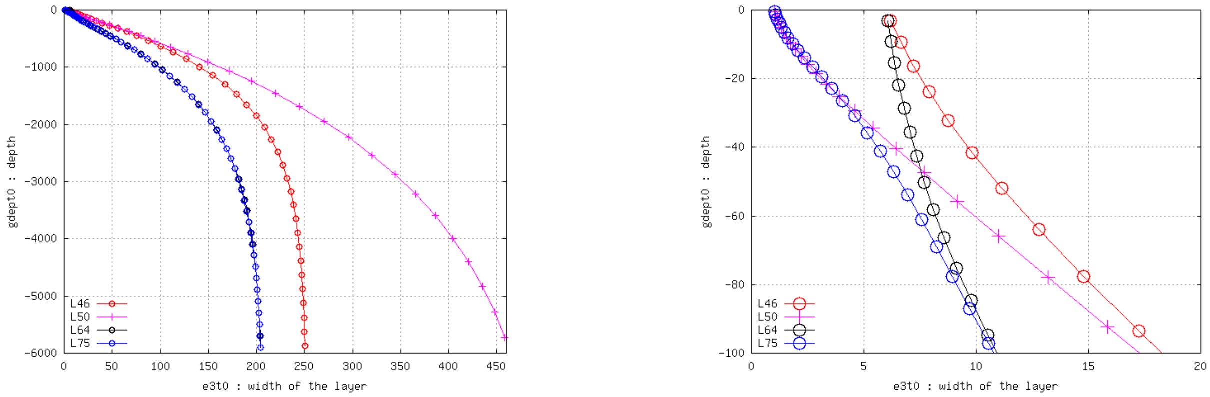


Figure 2: Vertical width of the layer for 46-level and 75-level configuration. Other existing vertical grid (50-level or 64-level) are shown for comparison.

2.4 Initial conditions

2.4.1 Ocean

All these simulations 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. For 75-level configuration, the annual mean Levitus field (*votemper_LEVITUS-ORCAR12_annual.nc* and *vosaline_LEVITUS-ORCAR12_annual.nc*) was interpolated on a 75-level ORCA12 grid with Sosie tool and was provided by Andrew Coward. For 46-level configuration, the monthly means Levitus field (*Levitus_p2.1_1m_01_12_Tpot_mms025_ORCA_R12.nc* and *Levitus_p2.1_1m_01_12_S_correc_mms025_ORCA_R12.nc*) was interpolated on a 46-level ORCA12 grid with Sosie tool and was provided by Markus Scheinert.

2.4.2 Ice

We use 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
/
```

2.5 Miscellaneous

During the entire simulations performed at MEOM-LEGI (1978-1982 or 1978-1992) we used a time step of 360 sec, except during first 8 days. Indeed, recurrent explosions when starting the simulation leads us to reduce the time step during first 8 days of the simulations. We start with a 50 sec timestep and then it was progressively increased to 360 sec. More details about starting strategy are given in section 4.

To resume the sensivity tests performed:

- L75-MAL83 (5 years): same configuration as NOCS (ORCA0083.L75-N01) except linear filtered free surface;
- L46-MAL84 (5 years): same as L75-MAL83 but we changed towards a 46-level configuration (and starts with monthly Levitus fields from Markus Scheinert);
- L46-MAL83 (5 years): same as L46-MAL84 but we (by error) limited the batymetry to 100m (10-level instead of 3);
- L46-MAL85 (15 years): same as L46-MAL84 but we changed momentum advection scheme from vector form to flux form.

3 Run production

4 Starting strategy

The ORCA12.L75-MAL83 simulation encountered some difficulties to start: recurrent explosions at steps 191 and 115 at points 983 2889[6] (Bering) and 3713 1963 (Mediterranean Sea, south of Greece).

We thus tried several starting strategies.

We first checked there was not any problem in forcing fields, by removing wind, and then fluxes in the routine *sbcblk_ core.F90*. But there was still the same explosion.

```
zwnd_i(:,:) = 0.e0
zwnd_j(:,:) = 0.e0
z_wnds_t(:,:)=0.0

qns(:,:)=0.0
emp(:,:)=0.0
emps(:,:)=0.0
qsr(:,:)=0.0
```

Then we decide to reduce timestep from 360 sec to 100 sec and to switch to a laplacian viscosity of 100, and then 300 m^2/s. We try it with different climatologies:

- Levitus (annual mean[7]) fields from Andrew: explosion at step 191 at Bering (i j = 983 2889), see fig. 3;

[6] this point will be filled (4000m) in the forecoming new bathymetry V3.1

[7] *votemper_ LEVITUS-ORCAR12_ annual.nc* and *vosaline_ LEVITUS-ORCAR12_ annual.nc*

- Levitus (annual mean[8], and then monthly means[9]) interpolated (by us) with Sosie tool: explosion at step 115 in Mediterranean Sea (i j = 3713 1963), see fig. 4;
- Levitus (january mean[10]) from Markus (at 46-level), interpolated at 75-level with *changezgr.ksh* script: explosion at Bering (i j = 983 2889).

We finally achieved to start from Levitus (annual mean) fields from Andrew, but with a time step of 50 sec, and a laplacian viscosity of $600 m^2/s$ [11]. Then we relax progressively (until day 8 of the simulations) the time step and the viscosity towards the standard values, as indicated in the next table.

DRAKKAR date	**Time step**	**rn_ahm0**	**operator type for lateral diffusion on momentum**
y1978m01d01-02	50 sec	600 m^2/s	laplacian
y1978m01d03	50 sec	400 m^2/s	laplacian
y1978m01d04	50 sec	200 m^2/s	laplacian
y1978m01d05	50 sec	100 m^2/s	laplacian
y1978m01d06	50 sec	-1.25E+010 m^4/s^2	biharmonic
y1978m01d07	100 sec	-1.25E+010 m^4/s^2	biharmonic
y1978m01d08	200 sec	-1.25E+010 m^4/s^2	biharmonic
y1978m01d09 until end	360 sec	-1.25E+010 m^4/s^2	biharmonic

The parameters of day 9 are then conserved for the entire period of the simulations, as described in section 1.2.2. In order to keep the simulations comparable between each other, we applied exactly the same starting strategy during the first 8 days of the other simulations (L46-MAL83/84/85). Note that for these 46-level simulations, the initial conditions were Levitus (monthly means) from Markus Scheinert.

In the forecoming new bathymetry V3.1 ([1]), the Bering point which blowed up will be filled (no depth greater than 4000m), as indicated below.

```
Print*, 'Limit hole at 4000m close to Bering'
ii0 =   980
ii1 =   995
ij0 =  2880
ij1 =  2905
DO ji = ii0, ii1
  DO jj = ij0, ij1
     bathy(ji,jj) = MIN( bathy(ji,jj) , 4000. )
  ENDDO
ENDDO
```

[8] *votemper_360x180-ORCA12.L75_annual_nomask_moy.nc* and *vosaline_360x180-ORCA12.L75_annual_nomask_moy.nc*

[9] *votemper_360x180-ORCA12.L75_annual_nomask.nc* and *vosaline_360x180-ORCA12.L75_annual_nomask.nc*

[10] *Levitus_p2.1_1m_01_12_Tpot_mms025_ORCA_R12.L75(_01).nc* and *Levitus_p2.1_1m_01_12_S_correc_mms025_ORCA_R12.L75(_01).nc*

[11] However Andrew Coward maintained he achieved to start only with a time step divided by 2

Figures 3 and 4 illustrate the problem we encountered in this region and in the Mediterranean region with the interpolated Levitus field: we see unrealistic fresh water at the bottom of the hole.

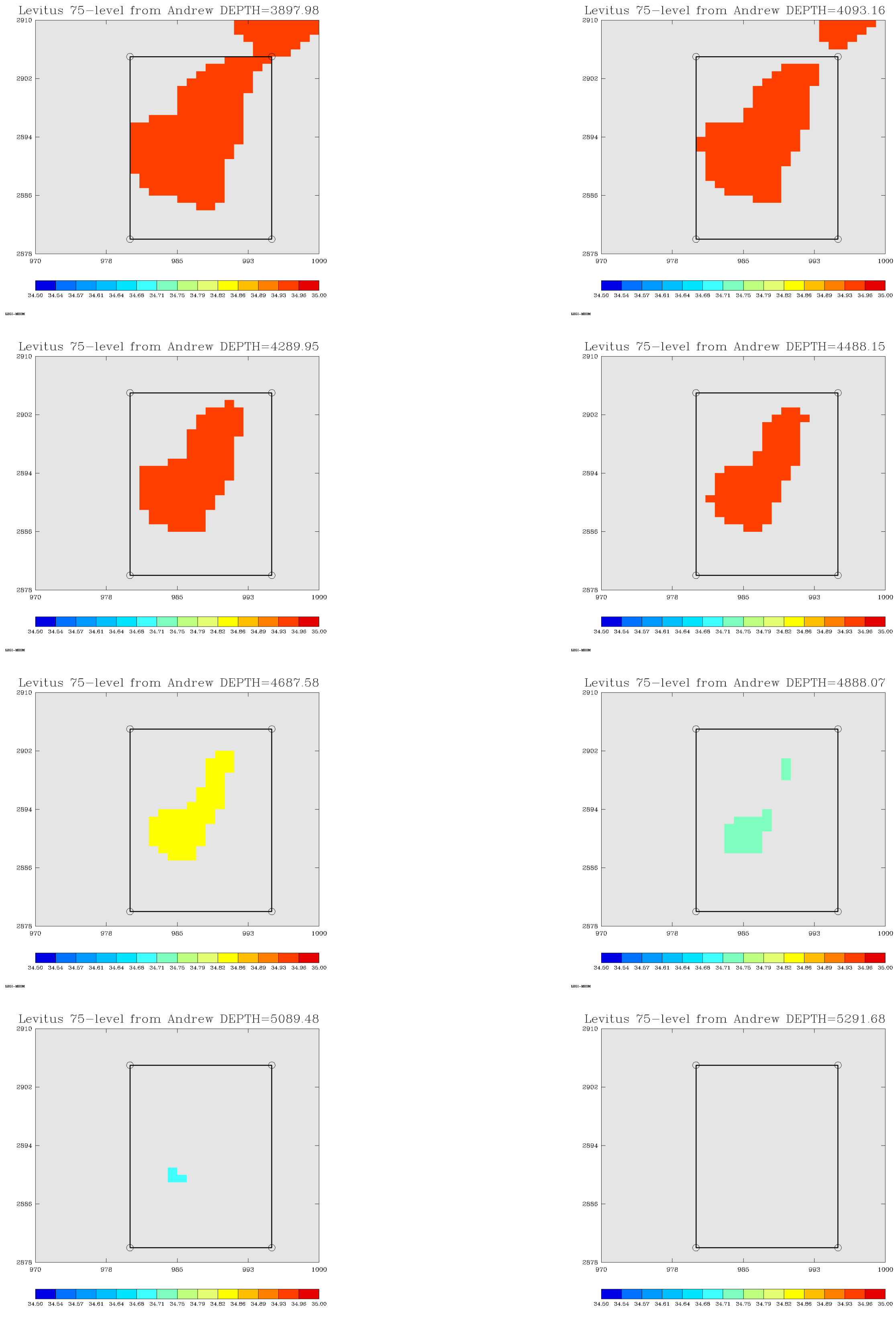


Figure 3: Levitus salinity fields (from Andrew Coward, NOCS) interpolated onto 75-level ORCA12 grid in the region of the explosion (Bering). Boxes indicate the region which will be filled deeper than 4000m in the forecoming bathymetry V3.1.

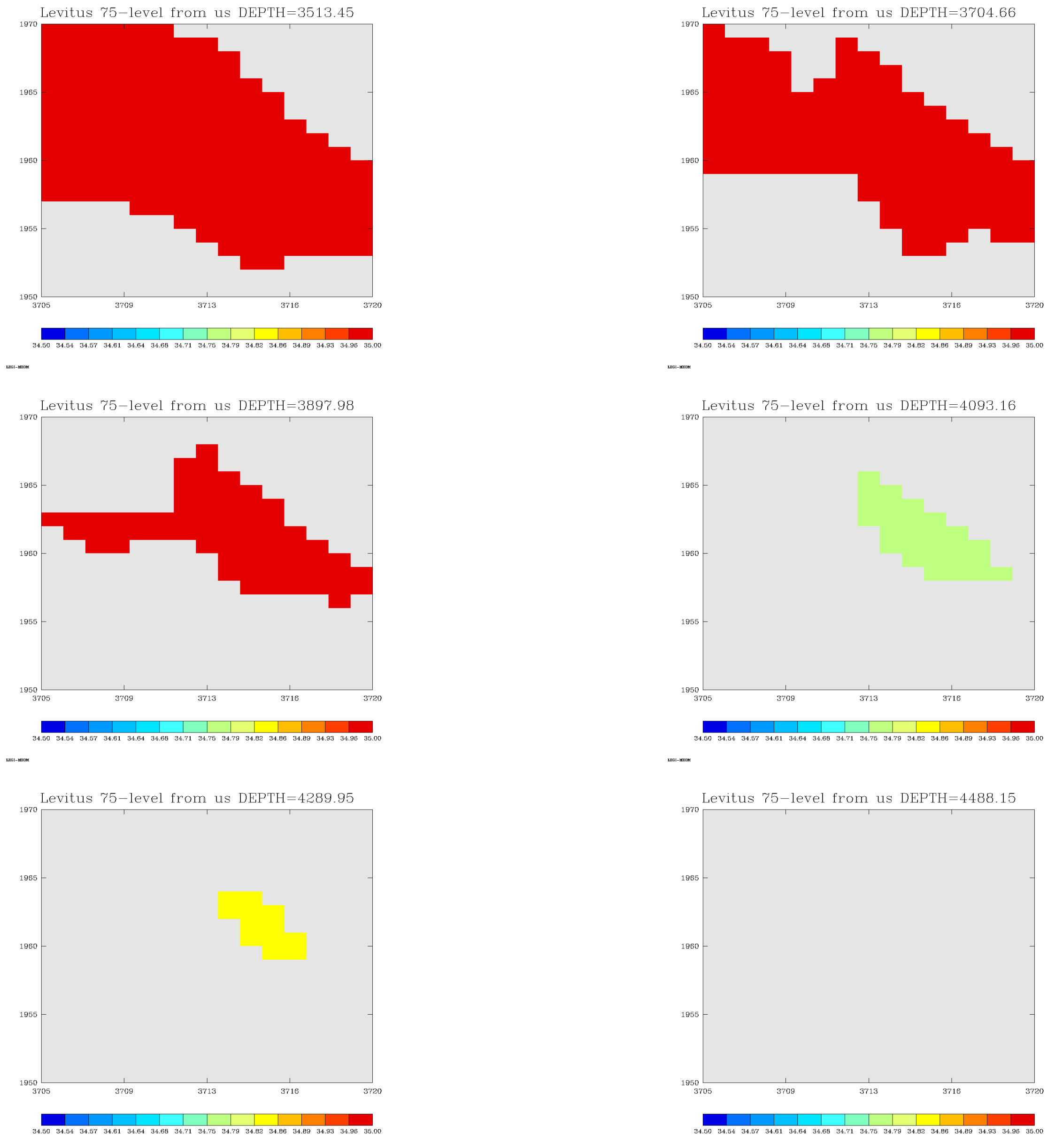


Figure 4: Levitus salinity fields (from MEOM) interpolated onto 75-level ORCA12 grid in the region of the second explosion (South of Greece). Nothing has been done in this region in the next bathymetry V3.1 (perhaps we still have problems in this region for the next simulations...)

4.1 Integration and computing performance

These runs started January, 1st, 1978 (start from rest) and ended December, 31st, 1982 (ORCA12.L75-MAL83 and ORCA12.L46-MAL83/84) or December, 31st, 1992 (ORCA12.L46-MAL85). The runs were performed at CINES HPC center in Montpellier, using 2056 cores of the SGI Altix ICE 8200 cluster (Jade). The domain decomposition used is 42 x 67 cores along x- and y- directions respectively for a total of 2056 computing core (land domain were eliminated). Each core computes 105 x 48 grid points. The placement strategy implemented was the same as for ORCA12.L46-MAL95/950 simulations (no “depopulated core condition” but “away-neighbour placement”). Next table resumes the computing performance of the set of simulations.

	L75-MAL83	**L46-MAL83**	**L46-MAL84**	**L46-MAL85**
CPU hours per simulated year	84476 ± 6452	56679 ± 5004	56255 ± 4070	60169 ± 5415
Elapsed hours per simulated year	41.1	27.6	27.4	29.3
Total CPU cost of entire simulation	422 382 CPU h (5 yrs)	283 394 CPU h (5 yrs)	281 276 CPU h (5 yrs)	902 536 CPU h (15 yrs)

The total CPU cost of this set of simulations reaches 1 889 588 CPU hours. More details about performance computing strategy can be found in [3] and on demand at albanne.lecointre@legi.grenoble-inp.fr. We performed 6-month runs with a 24h00 walltime, with a restart file frequency of 6 months [12].

4.2 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 in 46-level configuration and 2.8Tb in 75-level configuration (for 5-day + monthly and annual means). We also computed the climatologies over the period 1980-1982 (the last common 3 years of this set of simulations) and the climatology over the period 1983-1992 of ORCA12.L46-MAL85 (last 10 years of this simulation: to be compared to ORCA0083.L75-N01).

4.3 Journal of the run

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

5 Validation

The ORCA12.L75-MAL83 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). Only ORCA12.L75-MAL83 validation is shown here, validation for the other experiments are available on the Drakkar web site.

add a validation for the other L46 simulations ?

5.1 Mean state of the ocean (1980-1982)

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).

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

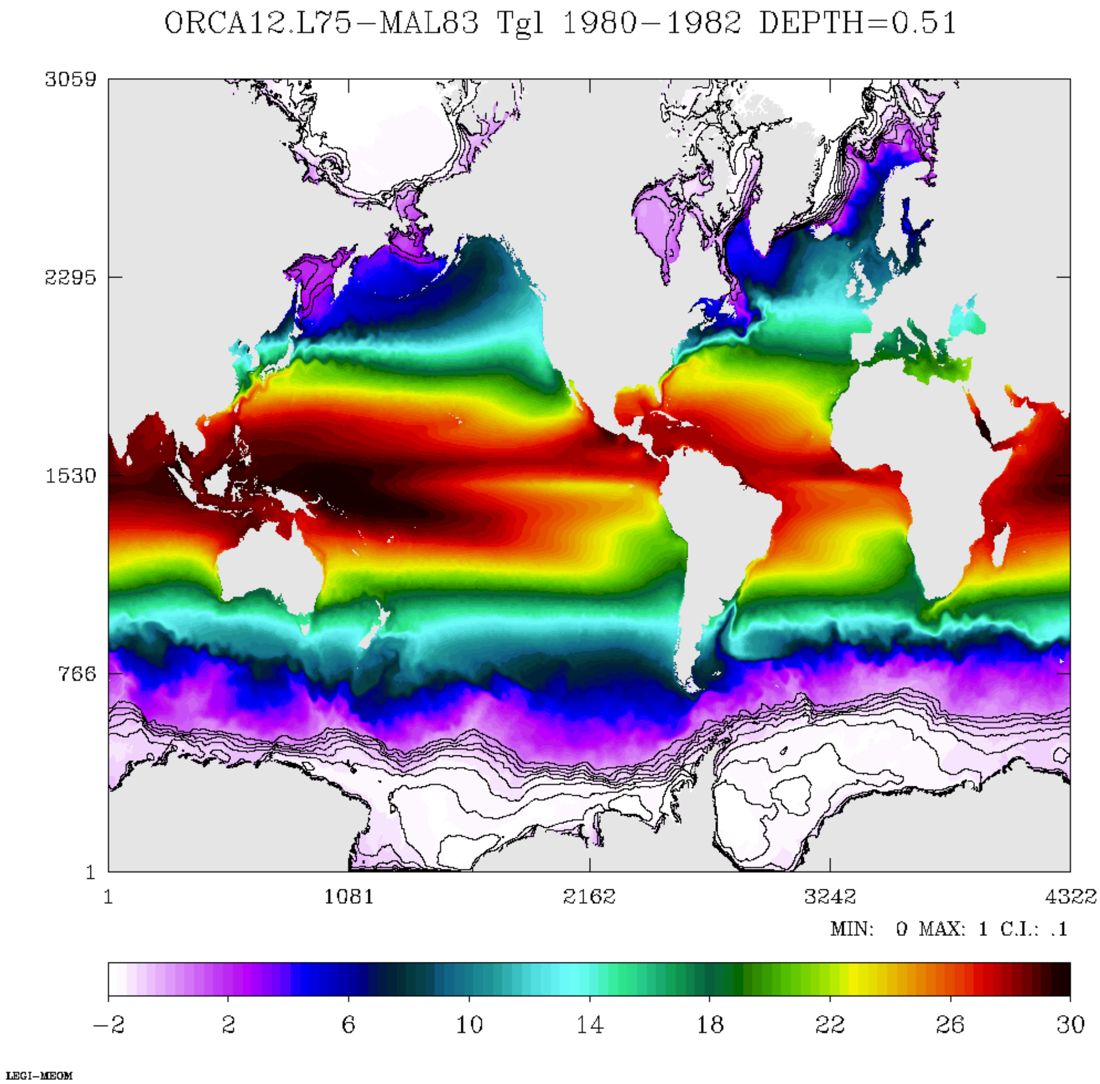


Figure 5: Mean Sea Surface Temperature over the period 1980-1982. Colours indicate the SST in ˚C, and contour lines indicate the sea ice thickness.

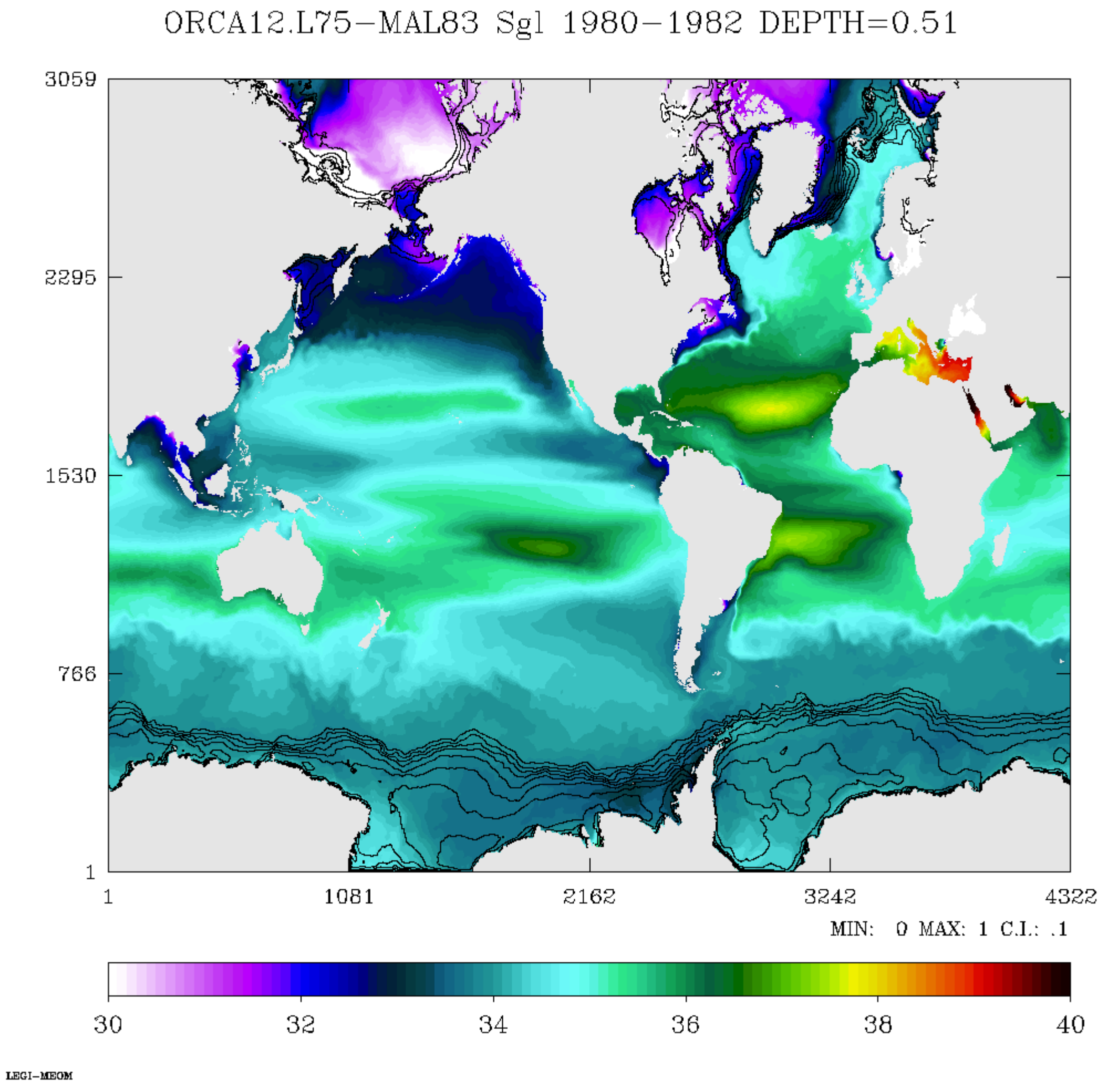


Figure 6: Mean Sea Surface Salinity over the period 1980-1982. Colours indicate the SSS, and contour lines indicate the sea ice thickness.

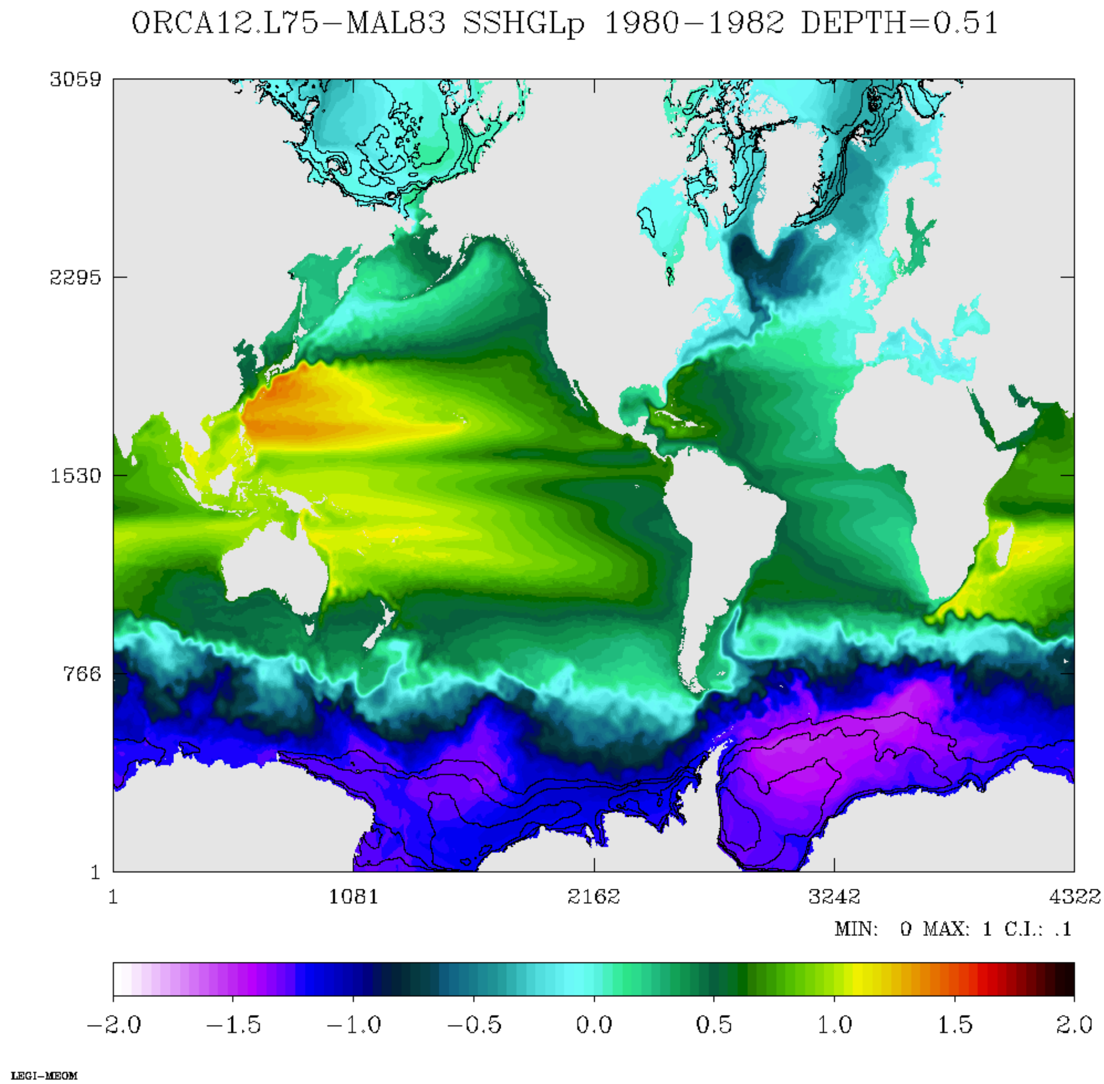


Figure 7: Mean Sea Surface Height over the period 1980-1982. Colours indicate the SSH in meters, and contour lines indicate the sea ice thickness.

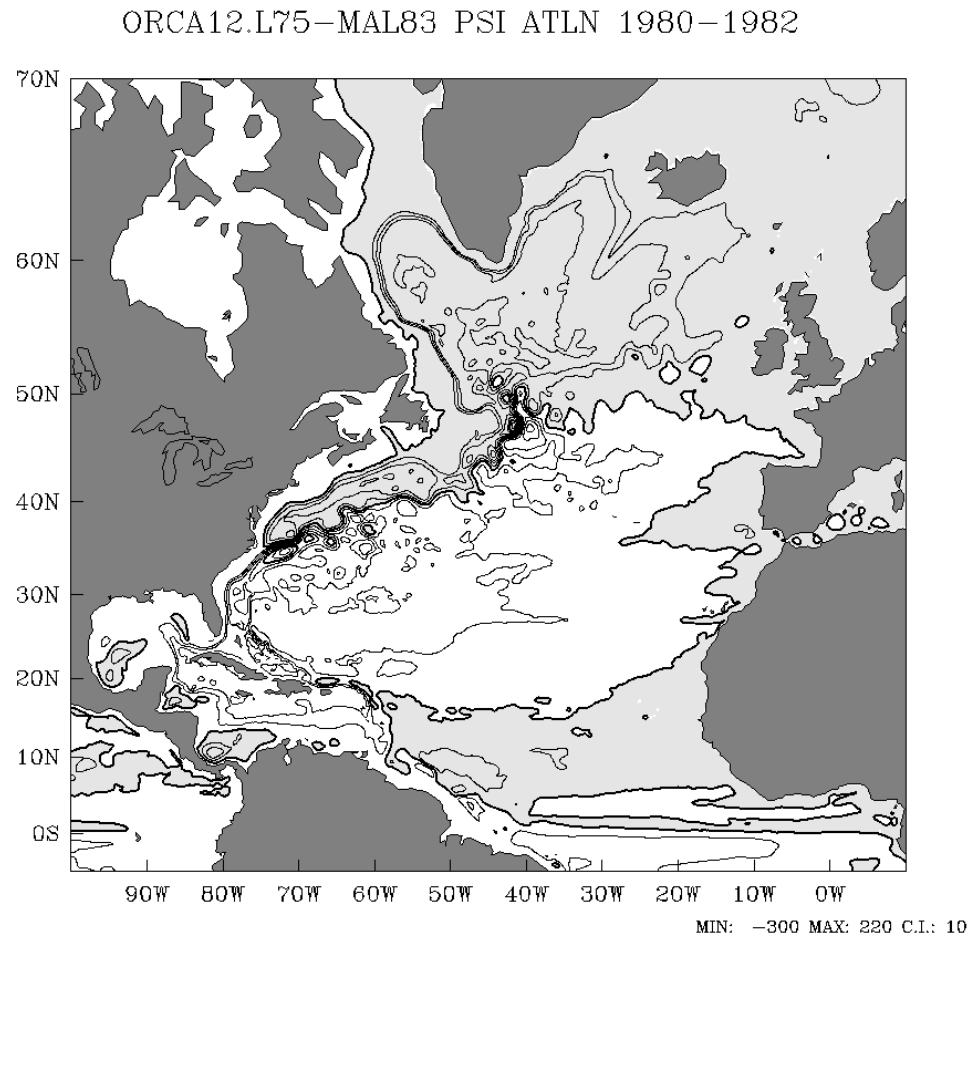
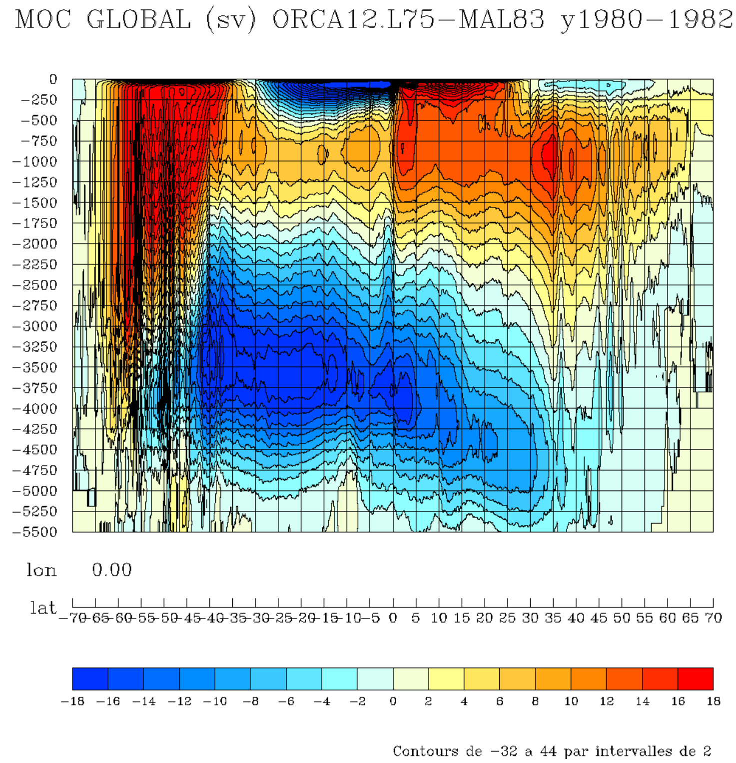


Figure 8: Mean Barotropic Streamfunction over the period 1980-1982. Contours by 10 Sv, negative values are shaded.



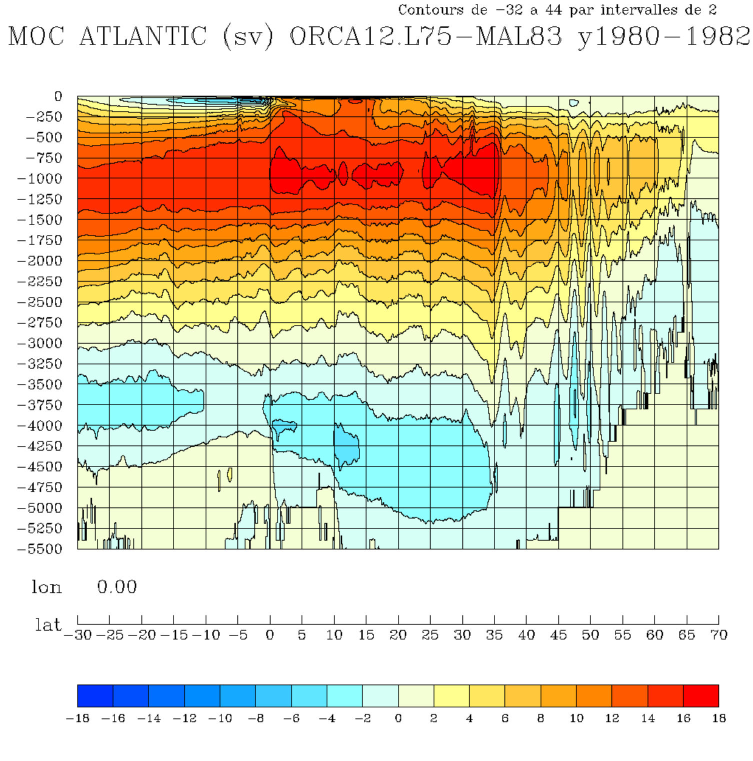


Figure 9: Mean Overturning over the period 1980-1982. Top: Global Ocean, bottom: Atlantic Ocean. Contours by 2 Sv.

5.2 Temperature and salinity CLASS1-1

The 3-year mean temperature difference with Levitus 2009 climatology at various depths (0m, 100m, 500m) is shown below.

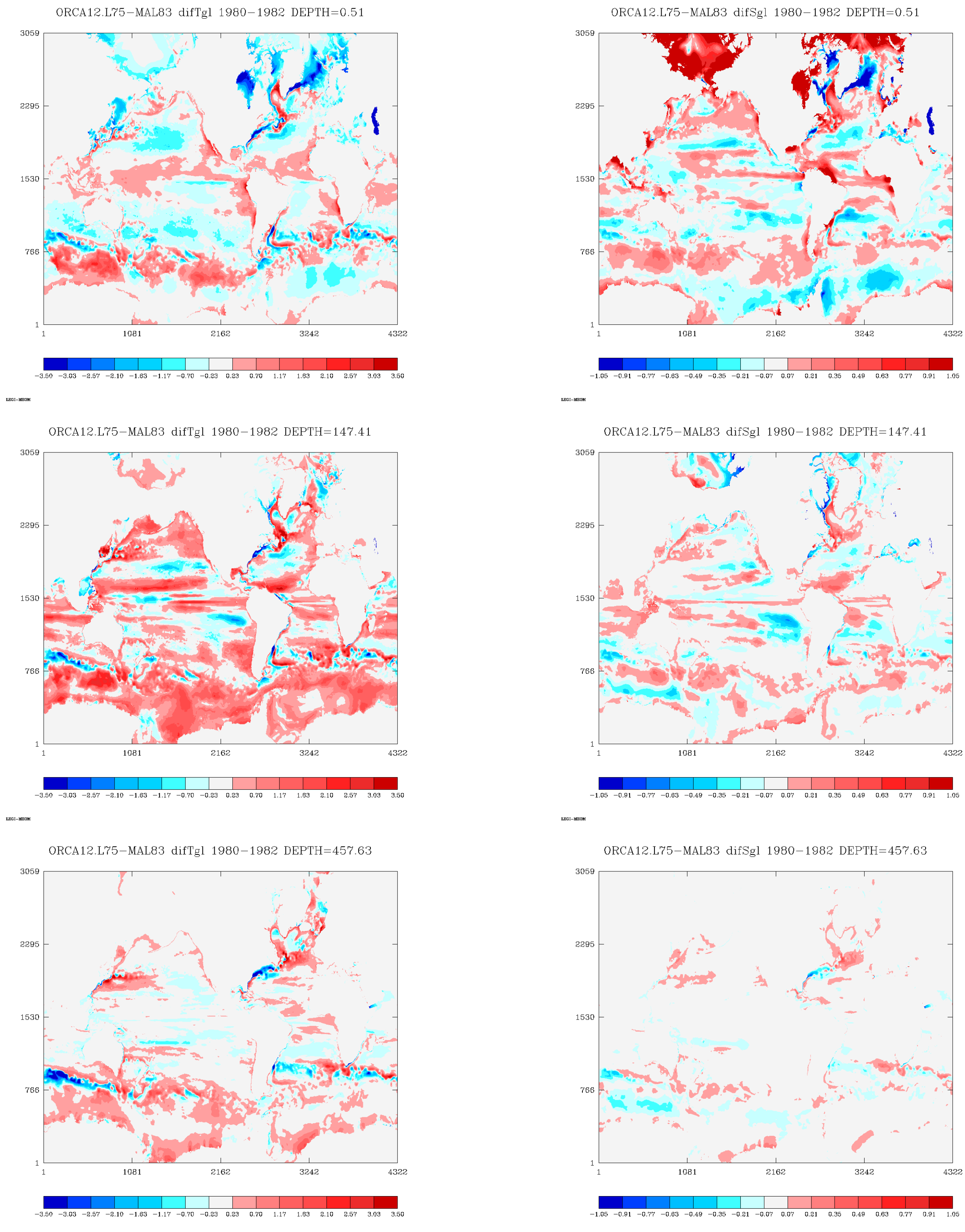


Figure 10: Difference between the 3-year mean temperature (left) and salinity (right) of the ORCA12.L75-MAL83 simulation with Levitus 2009 climatology at various depths (0m, 100m, 500m). Positive (negative) values indicate that the model solution is warmer or saltier (cooler or fresher) than the climatology.

5.3 Heat and Freshwater surface fluxes CLASS1-4

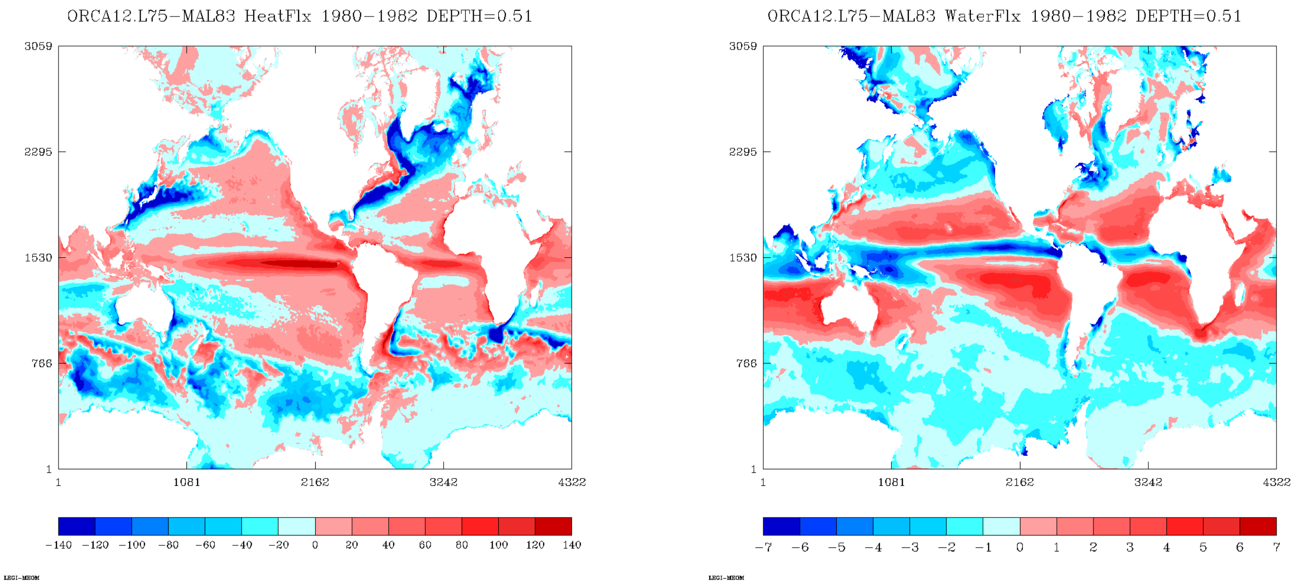


Figure 11: ORCA12.L75-MAL83 3-year mean net heat flux in W/m2 (left), and freshwater flux in mm/day (right).

5.4 Sea-Ice CLASS1-3

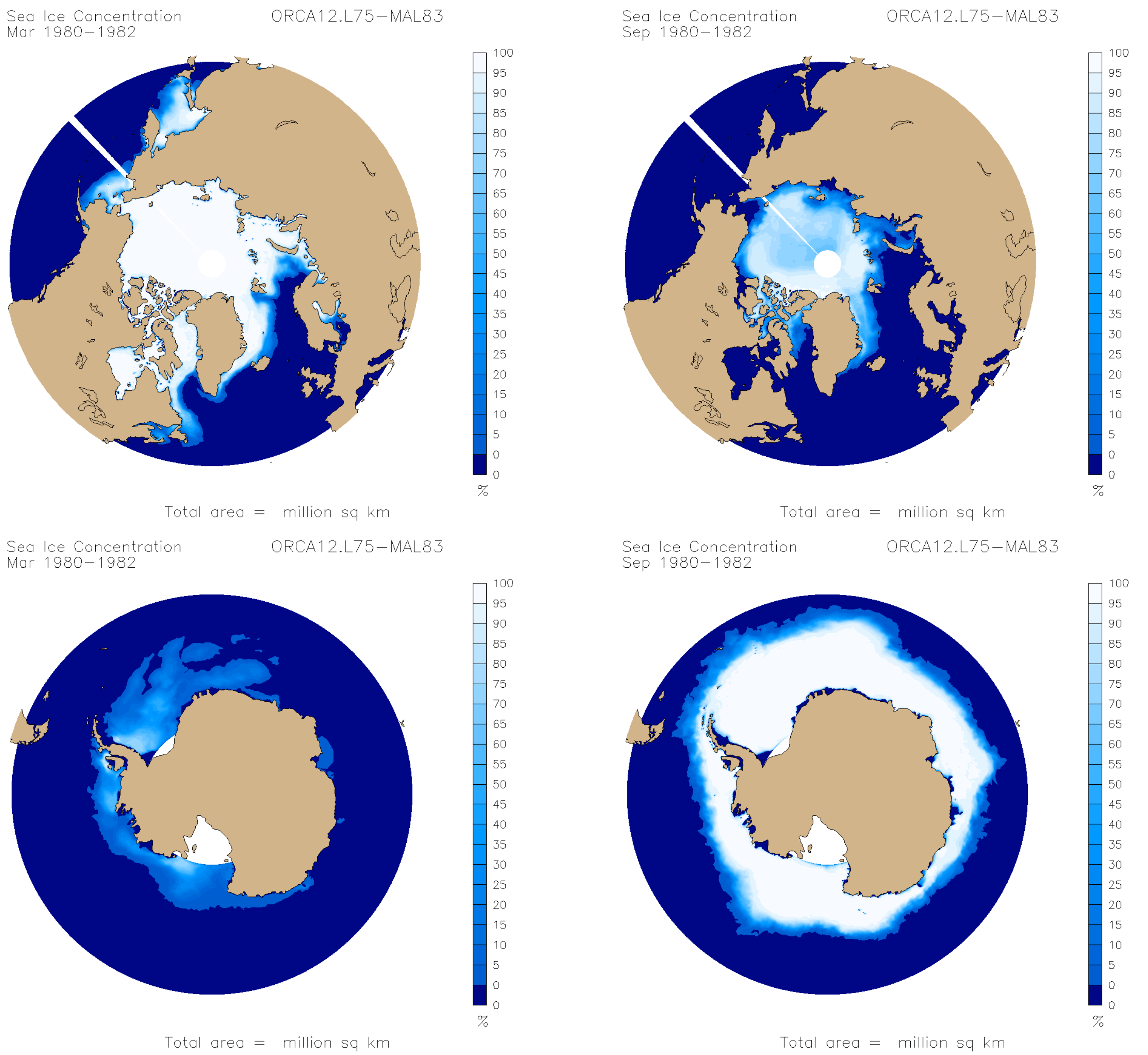


Figure 12: ORCA12.L75-MAL83 3-year mean sea-ice concentration in March (left) and September (right) in the Arctic (top) and in the Antarctic (bottom).

5.5 Variability

5.5.1 Temperature and salinity drifts

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

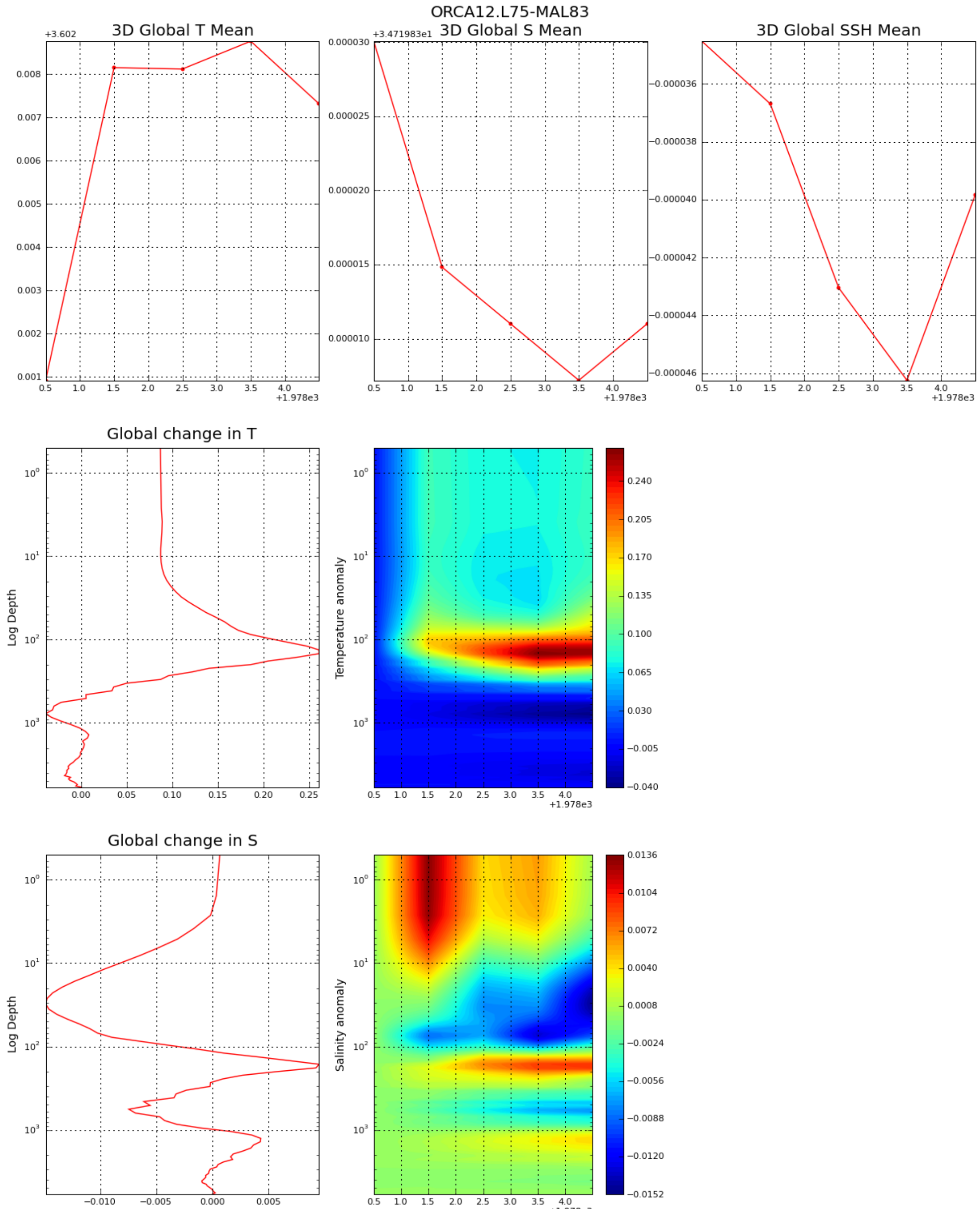


Figure 13: Top plots: Year-to-year variations of the world ocean average temperature and salinity over the integration period (1978-1982). Middle and bottom plots: Changes compared to initial condition in horizontally averaged temperature and salinity (vertical logarithmic depth range), left is the final minus initial profile, and right is the time evolution of the difference with initial condition.

5.5.2 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.

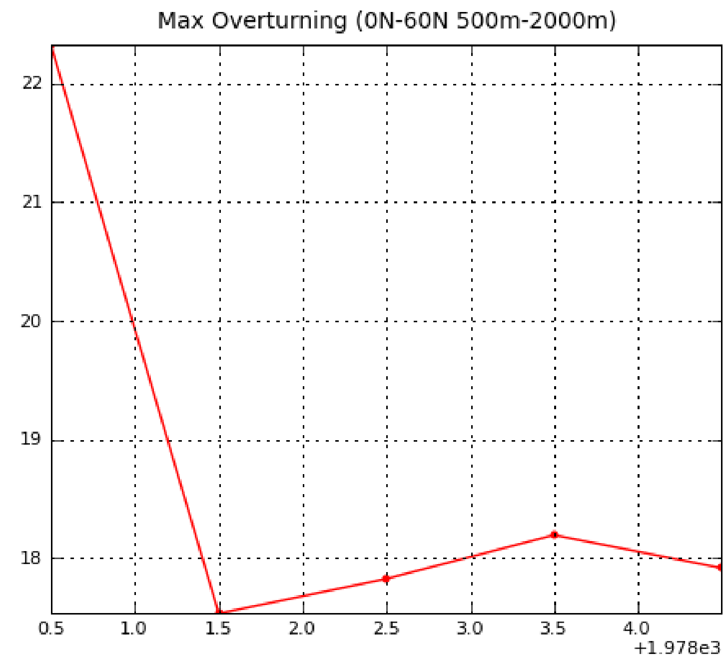


Figure 14: Variations of the annual mean maximum overturning (Sv) in the Atlantic Ocean over the integration period (1978-1982).

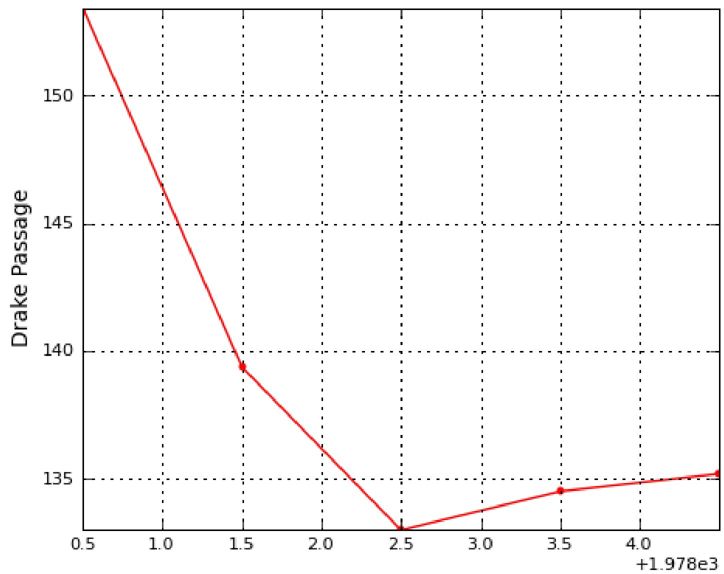


Figure 15: Variations of the annual mean transport (Sv) at the Drake Passage.

5.5.3 Sea-Ice variation CLASS1-3

We show here the variation of sea-ice characteristics and especially (CLASS1-3) the sea-ice concentration in summer 1978 (period of maximum sea-ice coverage) and in summer 1982 (period of minimum coverage). To be compared with satellite observations (if available).

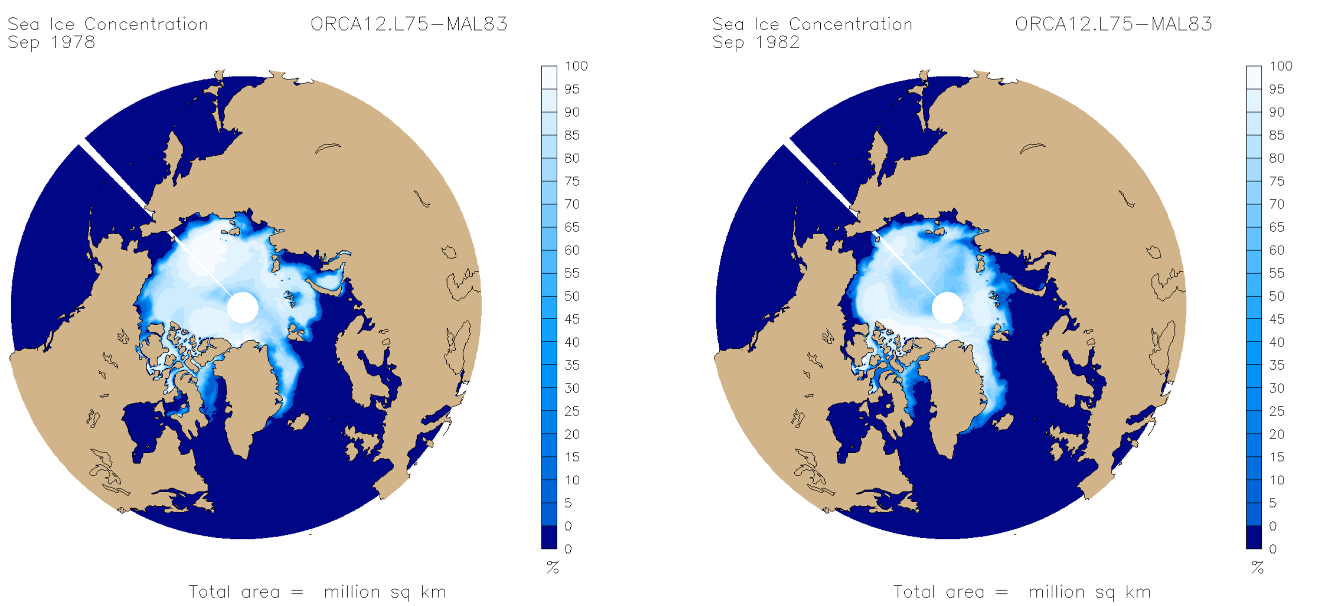


Figure 16: Sea-Ice Concentration (%) in the Arctic in September in 1978 (left) and in 1982 (right).

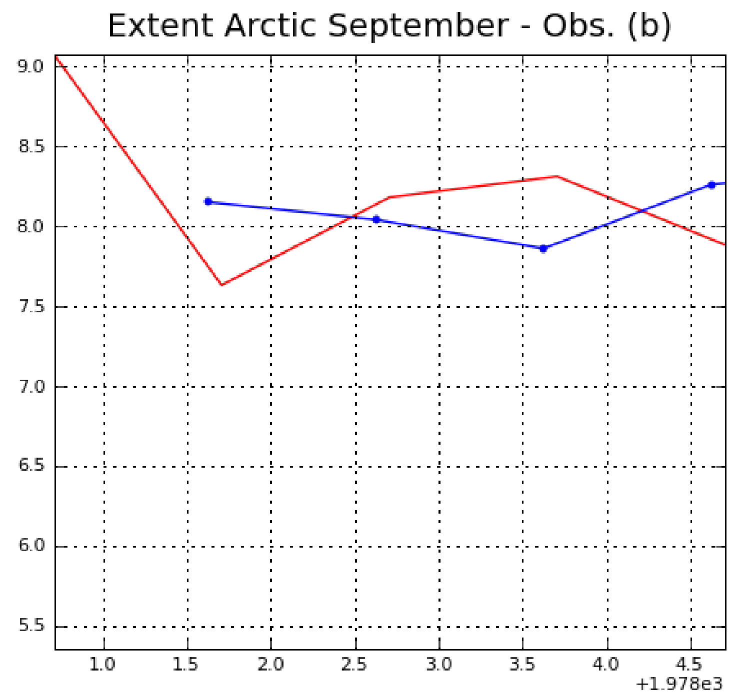


Figure 17: Sea-Ice Extent in September in the Arctic during the integration period (1978-1982). Blue curve is the model results and red curve is obtained from satellite observation. Annual means are centered on the middle of the year.

5.6 El Nino

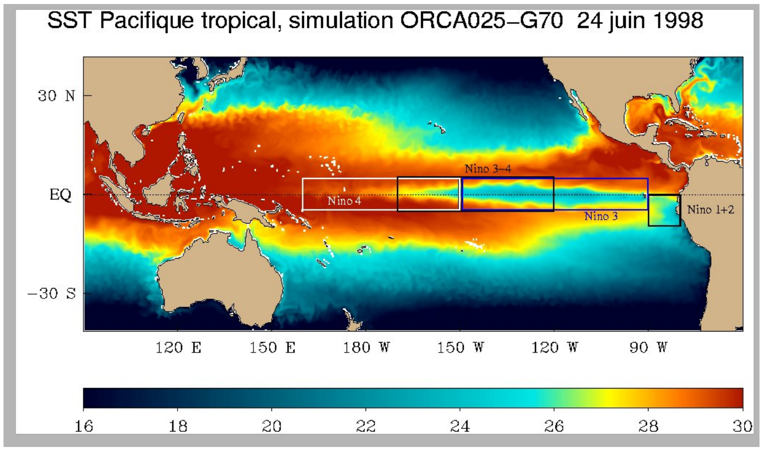


Figure 18: Definition of the Nino boxes.

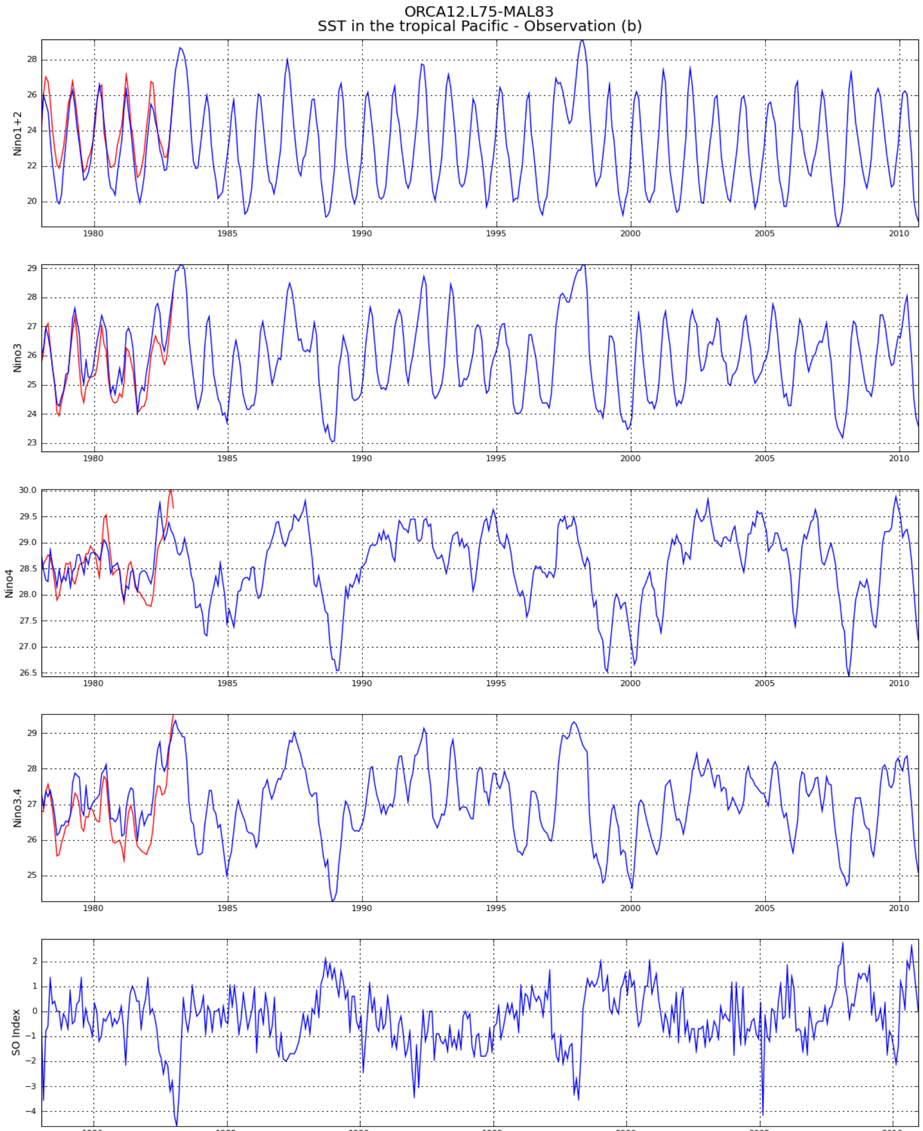


Figure 19: Monthly mean variations of the averaged temperature in el Nino boxes. Model is in black and observations (TOA array) are in green. Bottom plot is the Southern Oscillation index (monthly fluctuations in the air pressure difference between Tahiti and Darwin: sustained negative values of the 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] R. Bourdallé-Badie, A.-M. Treguier, J.-M. Molines, A. Coward, M. Scheinert, Lu Youyu, A. Lecointre, and B. Tranchant. The ORCA12 bathymetry V3.1. Technical report, Mercator, 2011.

[2] L. Brodeau, B. Barnier, T. Penduff, A.-M. Treguier, and S. Gulev. An ERA-40 based atmospheric forcing for global ocean circulation models.

[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] A. Lecointre, J.-M. Molines, and B. Barnier. Definition of the interannual experiment ORCA12.L46-MAL95, 1989-2007. Technical report, MEOM-LEGI, CNRS, Grenoble, France, 2011.