

Project

# Scientific Validation Report (ScVR) for V1 Reprocessed Analysis and Reanalysis

## WP 04 – GLO – CNRS\_LEGI Grenoble

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## TABLE OF CONTENTS

Introduction			
1. Nun	nerical code		
1.1.	Overview	6	
1.2.	Ocean details		
1.2.	1. Vertical physics		
1.1.	2. Horizontal physics		
1.1.	3. Bottom Boundary Layer	9	
1.1.4	4. Surface boundary conditions	9	
1.1.	5. Tracer damping strategy		
1.2.	Ice details		
1.2.	1. EVP rheology		
1.2.2	2. Thermodynamics		
2. Mod	lel configuration	11	
2.1.	Bathymetry		
2.2.	Horizontal grid		
2.3.	Vertical grid		
2.4.	Initial conditions		
2.4.	1. Ocean		
2.4.2	2. Ice		
2.5.	Restoring zones		
2.6.	Miscellaneous		
3. Mod	lel forcing	12	
3.1.	Forcing sources		
3.2.	Applied corrections		
3.3.	Specific setting		
3.3.	1. Diurnal cycle		
3.3.	2. Light penetration		
3.4.	River Run-off		
3.5.	Sea Surface Salinity restoring		
( D		10	
4. Kun	production		
4.1.	Integration		
4.2.	Model output		
4.3.	Journal of the run		
5. Vali	dation	13	
5.1.	Mean state of the ocean (2000-2009)		
We pr surfac	esent here maps of the time mean of the major ocean state variable (temperature, salin e height and barotropic transport streamfunction	ity, sea 13	
5.2.	Temperature and Salinity CLASS1-1		
5.3.	Heat and Freshwater surface fluxes CLASS1-4		
5.4	Sea-Ice CLASS1-3		
~			



Ref : MYO-WP04-ScCV-rea-CNRS

Date : 10/03/ 2011

Issue : 1.0

5.5. Va	riability	
5.5.1.	Temperature and salinity drifts	
5.5.2.	Overturning and Transport	
5.5.3.	Sea-Ice variation CLASS1-3.	
5.6. El 1	Nino	
6. Reference	ces	



Ref: MYO-WP04-ScCV-rea-CNRSDate: 10/03/ 2011Issue: 1.0

## Introduction

This report describes in details the ORCA025.L75-MJM95 simulation performed in the frame of the MyOcean project. This run is a free run, without data assimilation that provides a "state of the art" model solution that can be achieved without data assimilation and will serve as reference run for the reanalysis runs. Therefore is uses the exact same model configuration than for the renalyses (e.g. the 75 vertical levels) and the same exact atmospheric forcing variables (e.g. ERAinterim), but also uses specific customizations that are known to be required in non assimilated run, such as relaxation to surface salinity.

This report is organized in different sections. The first one deals with the details of the numerical code, and the parameterizations used. The second section describes the model configuration, e.g. the model grid, the input data of the model, and all other particular settings. A third section is dedicated to the forcing issues. The fourth section records technical details of the production of the run. Finally, the last section gives some elements of validation of the run.

## 1. Numerical code

1.1. Overview

This experiment was performed with version 3.2.1 of NEMO, with some particular developments described in the following paragraphs. Some of the adaptations are included in the DRAKKAR version of the code (rev. 401 of DCM), other are specific to this experiment done in the frame of MyOcean re-analysis. CPP keys used for compilation are:

CPP key name	Action:
key_orca_r025_I75	ORCA025 horizontal grid with 75 vertical levels
key_dynspg_flt	Filtered free surface
key_zdftke	Tke turbulent closure for vertical diffusion
key_zdftmx	Effect of internal tides on vertical mixing
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_lim2_evp	Use LIM2 ice model with EVP rheology
key_trabbl_dif	Use BBL enhanced diffusion on tracers
key_trabbl_adv	Use BBL specific advection for tracers
key_dynbbl_adv	Use BBL specific advection for momentum
key_tradmp	Use 3D regional restoring zones (description below)
key_trdmld	Compute and save mixed layer trends diagnostics.

### 1.2. Ocean details

1.2.1. Vertical physics

1.1.1.1. 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 areas: (a) The background avt coefficient is divided by 10 under ice. (b) the coefficient for surface input of tke (ebb) is



Issue : 1.0

reduced from 60 (open ocean) to 3.75 (ice covered regions). (c) Lang-Muir cells parametrization is turned off below ice.

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

! &namzdf_tke	!	turbule	nt (	eddy kinetic dependent vertical diffusion ("key_zdftke")
rn_ediff rn_ediss rn_ebb rn_ebbice	= = =	0.1 0.7 60 3.75	! ! !	<pre>coef. for vertical eddy coef. (avt=rn_ediff*mxl*sqrt(e) ) coef. of the Kolmogoroff dissipation coef. of the surface input of tke coef. of the surface input of tke under ice</pre>
nn_havti rn_emin	=	1 1.e-6	! !	horizontal shape for avtb (=1) or not (=0) under ice minimum value of tke [m2/s2]

	rn emin0	=	1.e-4	! surface minimum value of tke [m2/s2]
	rn hchoar	_	1 0.20	L background chear (SQ)
		-	2	: Date of the shear (-0)
	nn_mxt	=	3 ! mi	lxing 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
			1	= 3 same criteria as case 2 but applied in a different way
	nn ndl	_	1 I Dr	condtl number function of richteren number (=1, out=ndl/Di\toum)
	iii_put	-	: FI	
			! (	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	L interior buoyancy length scale minimum value
	rn_lmin0	_	0.001	L surface buoyancy lenght scale minimum value
	IU_CUTU0	=	0.01	surface buoyancy tengit scate infilmum value
	nn_etau	=	T	! exponentially deceasing penetration of the due to
				! internal & intertial waves
	! = 0	no	penetratio	on ( O(2 km) resolution)
	! = 1	add	itional tk	(e source (rn efr * en)
	· - 2	add	itional th	a source (in efr * en) applied only at the base of the mixed layer
	: - 2	auu	dditional tr	the second secon
	! = :	3 9	dditional	the source (HF contribution: mean of stress module - module of mean
st	ress)			
	nn_htau	=	1	! type of exponential decrease of tke penetration
	-			! = 0 constant 10 m length scale
				= 1.05 m at the equator to 30m at high latitudes
				= 2 30 meters constant depth penetration
			! optior	i used only id nn_etau /= 0
	rn_efr	=	0.05	! fraction of surface tke value which penetrates inside the ocean
			! optior	n used only if nn etau = 3
	rn addhft	=	-1.e-3	! add offset applied to the "mean of
			2.0 0	$\downarrow$ stress module - module of mean stress" (always kent > 0)
			1	: Stress module - module of mean stress (always Rept > 0)
	rn_scinit	=	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	-			
'				



Ref : MYO-WP04-ScCV-rea-CNRS

Date : 10/03/ 2011

Issue : 1.0

### 1.1.1.2. Tidal mixing

Tidal mixing is parametrized according to the works by Bessières et al. (2004) and Koch-Larrouy et al, (2006), using the following namelist parameters. The input tidal energy for M2 and K1 were provided by F. Lyard from a global tidal model.

```
!-----
&namzdf_tmx  ! tidal mixing parameterization
                                                             ("key_zdftmx")
                             !----
                     ! vertical decay scale for turbulence (meters)
! threshold of the Brunt-Vaisala frequency (s-1)
  rn_htmx = 500.
  rn n2min
            = 1.e-8
            = 0.333 ! tidal dissipation efficiency
  rn tfe
            = 0.2
                      ! mixing efficiency
  rn_me
                    ! ITF specific parameterisation
! ITF tidal dissipation efficiency
  ln_tmx_itf
           = .true.
  rn_tfe_itf = 1.
```

1.1.2. Horizontal physics

1.1.2.1. Tracers

We use a laplacian isopycnal diffusivity for tracers. The diffusivity is proportional to the local grid size (it decreases poleward).

```
_____
&namtra ldf ! lateral diffusion scheme for tracer
1.....
                 ! Type of the operator :
Ţ
  ln_traldf_lap = .true. ! laplacian operator
ln_traldf_bilap = .false. ! bilaplacian operator
                                bilaplacian operator
                      ! Direction of action
                                           :
  ln_traldf_level = .false. ! iso-level
  ln_traldf_hor
                               1
                                       horizontal (geopotential) (require "key_ldfslp" when
                 = .false.
ln sco=T)
  ln_traldf_iso
                         !
                                                       (require "key ldfslp")
                 = .true.
                                iso-neutral
                       ! Coefficient
1
  rn_aht_0
                 =
                   300.
                           !
                                horizontal eddy diffusivity for tracers [m2/s]
  rn_ahtb_0
                     0.
                           Ţ
                                background eddy diffusivity for ldf iso [m2/s]
                =
  rn_aeiv_0
                 =
                     0.
                           1
                                eddy induced velocity coefficient [m2/s]
/
```

#### 1.1.2.2. Momentum

We use a bi-harmonic viscosity for the lateral dissipation. The viscosity is proportional to the grid size power 3. This coefficient was changed during the integration in order to fix numerical instability. The run started with a bi-harmonic viscosity of -1.1  $10^{11}$  m<sup>4</sup>/s and ended with -1.8  $10^{11}$  m<sup>4</sup>/s. Details of the changes are given in the paragraph concerning the production.

```
&namdyn ldf
            1
                  lateral diffusion on momentum
|-----
                                               1
                         ! Type of the operator :
                   = .false. ! laplacian operator
= .true. ! bilaplacian operator
  ln_dynldf_lap
  ln_dynldf_bilap = .true.
                         ! Direction of action
  ln_dynldf_level = .false. ! iso-level
ln_dynldf hor = .true. ! horiz
  ln_dynldf_hor =
                                                                      (require "key ldfslp" in s-
                       .true.
                                         horizontal (geopotential)
coord.)
  ln_dynldf_iso
                 = .false. !
                                                                require "key_ldfslp")
                                    iso-neutral
                          ! Coefficient
 rn ahm 0
              = -1.1e11
                                     horizontal eddy viscosity if lap : >0
1
                               1
                                                                           [m2/s]
              = -1.8e11
                               !
                                     horizontal eddy viscosity if lap : >0
  rn ahm 0
                                                                           [m2/s]
                                                            if bilap : <0 [m4/s2]</pre>
                               ļ
  rn ahmb 0
                    0.
                               !
                                     background eddy viscosity for ldf_iso [m2/s]
             =
```



 Ref
 : MYO-WP04-ScCV-rea-CNRS

 Date
 : 10/03/ 2011

Issue : 1.0

#### 1.1.3. Bottom Boundary Layer

Bottom boundary layer parameterizations were used in this simulation, with all the enhancements developed by Hervieux (2008) at LEGI. Both diffusive and advective BBL parameterization are used for tracers. The parametrization of BBL advection for momentum was also used. Previous runs have shown that despite the fact that the effect of this parameterization is still unsatisfactory with regard to overflow modeling, it does have positive effects.

```
1.....
&nambbl
          ! bottom boundary layer scheme
1 - - - - - - - - -
           ------
                     ! diffusive bbl
                                                           ("key_trabbl")
1
1
                     1
                        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]
```

#### 1.1.4. Surface boundary conditions

The surface boundary conditions are prescribed to the model using the CORE bulk formulation. As detailed in a latter section, forcing fields are provided from ERA-interim products.

#### 1.1.4.1. Radiative flux correction

The radiation fluxes (both long wave and short wave) exhibit unacceptable bias. Therefore a specific correction has been implemented by Garric and Verbrugge (2010) in order to improve those fluxes. This correction 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 radiation fluxes. Original fields are band-pass filtered to separate large scales and small scales, using a shapiro filter, applied 250 times. The correction is applied to the large scale and then the small scale is added to produce the radiation fluxes for the model.

1.1.4.2. Light penetration algorithm according to ocean color.

In this simulation we use a non-standard parameterization of the penetration of the solar flux in the ocean, modulated by the chlorophyll concentration, deduced from satellite ocean color monthly climatology developed by Langaigne et al. (2007).

1.1.4.3. Diurnal Cycle on solar flux.

Due to the high vertical resolution near the surface, we implement a parameterization of the diurnal cycle on the solar flux. Input is the daily mean flux, which is spread over the day according to the time, and geographical position on the earth. This parameterization aims at better representing the night-time convection which takes place in the upper most layer (0-5m) of the ocean.

#### 1.1.4.4. SSS restoring strategy

This run uses Sea Surface Salinity restoring, with a time scale of 60 days/10 meters (considered as rather strong). The restoring is identical for the open sea and ice covered areas. It is enhanced by a factor of 5 in the Mediterranean Sea. The restoring term is bounded to a maximum absolute value of 4 mm/day (after the Med Sea enhancement). In this run, we implemented 2 changes to the standard SSS restoring: (a) The coastal area remain free of restoring. A fading coefficient (function of the distance to coast) is used, with a characteristic length scale of 150 km. (b) In the restoring term, the SSS difference between model and observation climatology (Levitus) is computed using a spatially filtered model field. The filtering is achieved with a shapiro filter applied 100 times.



Issue : 1.0

!
&namsbc_ssr ! surface boundary condition : sea surface restoring
!
! file name ! frequency (hours) ! variable ! time interpol. ! clim
'yearly' / ! weights ! rotation !
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
'monthly' ! filename ! pairing !
SN_SST = SST_OATA , 24 , SST , TALSE. , TALSE.
yearly, , , ,
$s_{12}s_{23}s_{23}s_{3}s_{3}s_{3}s_{3}s_{3}s_{3}s_{3}s_{$
jourcy , , ,
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 no
(=0)
nn_sssr = 2 ! add a damping term in the surface freshwater flux (=1) or no
(=0)
! or to SSS only (=1) or no damping term (=0)
! when hn_sssr = 2 damping term contributes to SSH
$rn_{a}$ and $rn_{a}$ = -40. : magnitude of the retroaction on temperature [w/m2/K]
$\ln (2eus) = -100.007$ : magnitude of the damping on satility (mm/day)
rn sssr bnd = 4.e0 · ABS(Max/Min) value of the damping erg term [mm/day]
In ssr flt = .true. ! flag to filter sss for sss restoring
<pre>ln_sssr_msk = .true. ! flag to use distance to coast to weight SSS restoring</pre>
<pre>sn_coast = 'distcoast' , 0 , 'Tcoast' , .false. , .true.</pre>
'yearly', '', , ''
rn_dist = 150. ! Decaying length scale (km) for SSS retoring fading near the coast
1

### 1.1.5. Tracer damping strategy

There are some very well identified and unfortunately robust flaws in the simulations, basically linked with the poor representation of the overflows. The main concerns are for the Mediterranean Sea outflow, and the Antarctic Bottom Water. The semienclosed seas such as the Red Sea, Black Sea of Persian Gulf have very specific water mass properties and act as reservoir for the open ocean. In order to fix those major flaws, or to keep water mass properties in the reservoir, we decided to use some restoring of temperature and salinity in very specific areas.

1.1.5.1. Regional 3D damping (semi-enclosed seas)

For the semi-enclosed seas already mentioned (Red and Black Seas, Persian Gulf) we apply a 3D T ad S restoring with a time scale of 180 days.

1.1.5.2. Downstream the overflows

In the Gulf of Cadix, downstream Gibraltar strait, we have a very localized (and strong restoring), in the depth range 600-1300m, with a time scale of 6 days.

In the Gulf of Aden, downstream Bab-el-Mandeb, we have the same kind of restoring (same time scale) but over the whole water column.

The last spot where we have such a restoring is in the Arabian Gulf, downstream of the Ormuz Strait.

1.1.5.3. Antarctic Bottom Water Restoring

In order to refrain the erosion of the AABW in the Southern Ocean (lack of production, or miss representation of the down-slope motion), and according to a series of dedicated experiments (Dufour, Le Sommer, 2009), we decided to implement a 3D, T and S weak restoring (time scale of 2 years) in an area limited by the sigma-2=34.7 isopycnal, a depth greater than 1000 m and south of 30 S.



#### 1.2. Ice details

#### 1.2.1. EVP rheology

This simulation used the LIM2 model, but with the Elasto-Visco-Plastic rheology, similar to the LIM3 rheology. The ice-ocean coupling is done every 5 model steps, but the wind stress is computed at every time step. This proved to be efficient to fix model instability that was observed previously.

1.2.2. 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.

## 2. Model configuration

2.1. Bathymetry

The bathymetry for this run was built from etopo1 for the deep ocean and gebco1 for the coastal areas and shelves. The minimum depth in the model was set to 12 meters, except in the Bahamas region (~ 3 meters), the Torres Strait (~5 meters). The Palk Strait has been closed.

2.2. Horizontal grid

The horizontal grid is the standard ORCA025 tri-polar grid (  $1440 \times 1021$  grid points). The  $\frac{1}{4}$  degree resolution corresponds to the equator. Resolution increases poleward (the grid size is scaled by the cosine of the latitude, except in the Arctic, of course).

2.3. Vertical grid

The vertical grid have 75 levels, with a resolution of 1m near the surface and 200 meters in the deep ocean. (cf. table )

- 2.4. Initial conditions
  - 2.4.1. Ocean

The simulation started at rest, with initial climatological temperatures and salinities. The used climatology is a merge of the Levitus 98 climatology, patched with PHC2.1 for the Arctic regions, and Medatlas for the Mediterranean Sea.

2.4.2. Ice

Initial conditions for ice (ice concentration, ice thickness) was inferred from the NSDIC Bootstrap products for January 1989.

2.5. Restoring zones

The 3D restoring implemented in this simulation, as described above, uses the Gouretski annual climatology. This climatology was built using interpolation on isopycnal surfaces and is by far more suitable for the AABW restoring that the monthly Levitus Climatology.

2.6. Miscellaneous

Time step : at the beginning of the run we used a time step of 1080 sec. We had to reduced it to 960 sec at the end due to repeated model instability. We even decreased it to 540 sec to be able to pass very strong atmospheric events.

Ref: MYO-WP04-ScCV-rea-CNRSDate: 10/03/ 2011Issue: 1.0

### 3. Model forcing

#### 3.1. Forcing sources

The model was forced by ERA-interim reanalysis products. 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 precip, snow) and the total cloud cover (tcc) (all five last variables given as daily average).

#### 3.2. Applied corrections

In this simulation, input ERA-interim fields were taken without corrections except for the radiative fluxes. For those fluxes, Garric and Verbrugge (2010), computed a correction factor based on the comparison between ERA-Interim fluxes and satellites fluxes products (GEWEX). Only the large spatial scale is corrected, the small scale remaining unchanged.

- 3.3. Specific setting
  - 3.3.1. Diurnal cycle

The daily averaged short wave flux is spread over the day in order to represent the solar diurnal cycle. (Bernie, 2002). This is an important features according to the high vertical resolution in the upper ocean (1m), for representing the nighttime convection.

3.3.2. Light penetration

The parametrization of the light penetration in the ocean is implemented and we use a monthly chlorophyll surface concentration climatology deduced from SeaWIFS ocean color product.

3.4. River Run-off

The river run-off data is inferred from Dai and Trenberth (2002). It includes 109 major rivers and a coastal runoff. Data are collected in a monthly climatology. The mean runoff is 1.26 Sv. The runoff along the antarctic coast was separated in 3 equal parts: (1) the continental runoff, (2) ice-shelf runoff and (3) icebergs vealing. In the actual state of the model, ice shelf processes are not parametrized, so that part 1 and 2 are merged together and forms the coastal runoff, applied on 3 grid points from the coast. Part 3, is spread in the whole region south of 60 S.

3.5. Sea Surface Salinity restoring

As already stated in the code section, an SSS restoring is used with a time scale of 60 days for 10 m. It is implemented using some new features (distance to coast, shapiro smoothing, bounded values). The limitation of the restoring in the vicinity of the coast requires particular care in the preparation of the dist.coast file, to avoid unwanted limitations such as in very narrow seas (Red Sea for instance). The screening of the dist.coast file takes care of the narrow areas, but after the run we discover the strong impact of very small islands, which are represented in the model (especially in the western tropical pacific), switching off the SSS restoring in quite a large area, hence producing a local strong drift.

### 4. Run production

4.1. Integration

The run started January, 1, 1989 and ended December, 31 2009, corresponding to the available ERA-interim forcing field. It was performed at CINES HPC center in Montpellier, using 856 core of the SGI Altix ICE 8200 cluster (jade) (Grant GENCI X2010010727).



Ref : MYO-WP04-ScCV-rea-CNRS Date : 10/03/ 2011 Issue : 1.0

#### 4.2. Model output

Model output is done as 5-days averages. Then monthly and annual means are computed in the post-processing.

4.3. Journal of the run

A journal of the run which reports on every technical incident that occurred during the model integration (e.g. changes in time step or biharmonic viscosity coefficient required to assure model stability) is available on demand at <u>jean-marc.moline@legi.grenoble-inp.fr</u>).

## 5. Validation

The validation of the MJM95 validation that is presented here is extracted from the monitoring of the experiment, available on demand on the Drakkar web site (contact <u>bernard.barnier@legi.grenoble-inp.fr</u>).

#### 5.1. Mean state of the ocean (2000-2009)

We present here maps of the time mean of the major ocean state variable (temperature, salinity, sea surface height and barotropic transport streamfunction.





Figure 1: Mean Sea Surface Temperature over the period 2000-2009. Colours indicate the SST in °C, and contour lines indicate the sea ice thickness.

Ref : MYO-WP04-ScCV-rea-CNRS

Date : 10/03/ 2011

Issue : 1.0



ORCA025.L75-MJM95 Sgl 2000-2009 DEPTH=0.51

Figure 2: Mean Sea Surface Salinity over the period 2000-2009. Colours indicate the SSS, and contour lines indicate the sea ice thickness.



ORCA025.L75-MJM95 SSHGLp 2000-2009 DEPTH=0.51

Figure 3: Mean Sea Surface Height over the period 2000-2009. Colours indicate the SSH in meters, and contour lines indicate the sea ice thickness.

Ref : MYO-WP04-ScCV-rea-CNRS

Date : 10/03/ 2011

Issue : 1.0



Figure 4: Mean Barotropic Streamfunction over the period 2000-2009. Contour by10 Sv.

-2500

-2750 -3000 -3250 -3500 -3750 -4000 -4250 -4250 -4500 -4750 -5250 -5250

lon

0.00

-16

-16 -14 -12 -10 -8

Ref : MYO-WP04-ScCV-rea-CNRS

Date : 10/03/ 2011

Issue : 1.0





Contours de -32 a 14 par intervalles de 2 Figure 5: Mean Overturning over the period 2000-2009. left : Global ocean, right : Atlantic Ocean. Contour by 2 Sv.

lat\_30-25-20-15-10-5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70

-2

-8 -4

2

, LUM

6 8

10 12 14 18



#### 5.2. Temperature and Salinity CLASS1-1

The 10-year mean temperature difference with Levitus 2009 climatology at various depths (0m, 100m, 300m, 800m, 2000m) is shown below.





-63 68 02 68 05 12

0 10 21 24 27 20





-68 -46 -48 -25 -88 -25 -28 -15 -18 -85 69 55 18 15 20 25 28 25 48 45 55



-10 -39 -08 -67 -04 -63 -04 -63 -02 -61 00 01 62 02 64 00 68 07 68 09 1





Ref : MYO-WP04-ScCV-rea-CNRS

Date : 10/03/ 2011

Issue : 1.0

-01 06 0.0 01 01 02 02 02 02 04 04 04 0.4 0.4



Figure 6: Difference between the 10-year mean temperature (left) and Salinity (right) of the MJM95 simulation with Levitus 2009 climatology at various depths (0m, 100m, 300m, 800m, 2000m). Positive (negative) values indicate that the model solution is warmer or saltier (cooler or fresher) than the climatology.

64 95 68 07 68 09 80

22 -0.1 32 21 02 22



- : 10/03/ 2011
- : 1.0 Issue

### 5.3. Heat and Freshwater surface fluxes CLASS1-4



Figure 7: MJM95 10-year mean net heat flux (W/m<sup>2</sup>) (left), and freshwater flux (mm/day) (right).

### 5.4. Sea-Ice CLASS1-3





Figure 8: MJM95 10 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 9: Top plot: Year to year variations of the world ocean average Temperature and Salinity over the integration period (1989-2009). 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.

Ref : MYO-WP04-ScCV-rea-CNRS Date

: 10/03/ 2011

Issue : 1.0

#### 5.5.2. Overturning and Transport

We show the variations during the model integration of two important climatic indexes which are the strength 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 in the Atlantic ocean over the integration period (1989-2009). Units are SV



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

Issue : 1.0

### 5.5.3. Sea-Ice variation CLASS1-3.

We show here the variation of sea-ice characteristics, and especially (CLASS1-3) the seaice 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 %) in September in the Arctic, left : 1996, and right : 2007.



Figure 13: Sea Ice Extent in September in the Arctic during the integration period (1989-2009). Blue curve is the model results, and the red curve is obtained from satellite observation. Annual means are centred on the middle of the year.



- Date : 10/03/ 2011
- Issue : 1.0

### 5.6. El Nino



Figure 14 : Definition of the Nino boxes.



Figure 14: Monthly mean variations of the averaged temperature in el Nino boxes. Model is in black and observations (TOA array) are in green.



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Issue : 1.0

### APPLICABLE AND REFERENCE DOCUMENTS

## Applicable Documents

	Ref	Title	Date / Issue
DA 1		Guidelines for the development and validation of pre-operational GMES Fast Track Services	April 2007
DA 2	MYO-MGT-DOW	My Ocean Management: Description of Work	March 2009 6.1

### **Reference Documents**

	Ref	Title	Date /
			Issue
DR 1			
DR 2			