A regional version of the NEMO ocean engine on the Mediterranean Sea: NEMOMED8 user's guide

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Mai 2009

Note de travail du Groupe de Météorologie Grande Echelle et Climat

N°107

METEO-FRANCE CNRM

Contents

1 Historic of the model

A middle-resolution or eddy-permitting Mediterranean Sea ocean model was first needed for climate purposes at Meteo-France/CNRM in year 2000. The scientific goals were to study (i) the interannual variability of the Mediterranean Sea circulation, (ii) the regional air-sea coupled system and (iii) the impact of the climate change on the Mediterranean Sea and climate. At the time, MED16 ([Béranger et al. 2004]) was the only available model in the French community as a basin-scale, process-oriented regional model covering the whole Mediterranean Sea at a 1/16° resolution. This model was actually developed from the MERCATOR PAM model ([Drillet et al. 2005]) covering the North-Atlantic ocean and the Mediterranean Sea. These models are all based on the version 8.1 of the OPA code ([Madec et al. 1998]). In year 2000, it was decided to develop OPAMED8 (1/8° resolution), a version that is easier to run for climate-scale simulations than PAM or MED16. OPAMED8 is the first regional model of the Mediterranean Sea used at CNRM and has been used for scientific studies since then in an ocean stand-alone mode ([Sevault and Somot 2005], [Somot 2005], [Somot et al. 2006], [Herrmann et Somot 2008], [Somot and Colin 2008], [Tsimplis et al. 2008a], and [Tsimplis et al. 2009]) and in an atmosphere-ocean coupled mode ([Sevault et al. 2002], [Somot 2005], [Somot et al. 2008], and [Tsimplis et al. 2008b]). Using the same grid and bathymetry, the OPAMED8 model has been then upgraded to the version 8.5 of OPA at IPSL ([Bozec et al. 2008]). This version of the model is often called MED8. Recently the IPSL/LOCEAN laboratory has developed the version 9 of the OPA code included into the so-called NEMO framework ([Madec 2008]). It allows a lot of new facilities from technical and scientific points of view. Consequently CNRM decided to develop a MED8 version of NEMO (more precisely NEMO-v2). This new model called NEMOMED8 is based on the same grid as OPAMED8 but includes many different choices in terms of bathymetry, physics, running options. The goal of this user's guide is to describe this new model already used at CNRM (and recently at IPSL/LMD) for scientific studies and national or european scientific projects (FP6-CIRCE, ANR-MEDUP, ANR-CICLE, LEFE-MISSTERRE, ERANet-CANTICO, HyMex). Even if NEMOMED8 will be used in the coming years, it is already time to think about developing the next generation of the Mediterranean Sea model. The French community of the Mediterranean modelling is now engaged into the development of eddy-resolving NEMO-MED12 model (version 3 of NEMO) in the frame of the PPR-MERCATOR NEMOMED project.

2 Presentation of NEMOMED8

The NEMOMED8 regional model of the Mediterranean is a new configuration of NEMO-v2-OPA, in the same order as ORCA2-LIM. It is a regional version, with specific aspects at its boundaries, like the use of an Atlantic buffer zone, and the treatment of the Black Sea as a river.

The NEMOMED8 model initially makes it possible to represent the thermohaline circulation in this basin. It is imposed by the water and heat losses on its surface, that's why much attention must be paid to the fluxes which are imposed to the model. From there, the fields of study which we explore are as follows:

- study of the Mediterranean Sea interannual variability and trends, with comparison to the observations when the model is forced by fluxes coming from dynamical downscaling of the ERA40 reanalysis fluxes or ECMWF analysis;
- simulation of the impact of climate change: we compute various simulations of the 21st century following scenarios from the IPCC;
- comparison between forced and coupled simulations: impact of an interactive Mediterranean on the climate and/or impact of an interactive atmosphere on the Mediterranean Sea;
- use of the fields resulting from NEMOMED8 simulations to force coastal ocean models at their boundaries (Gulf of Lions, Gulf of Gabes, Aegean Sea).

This documentation will focus on the specificities of NEMOMED8, one will find all the informations about the NEMO ocean engine in [Madec 2008].

Typographic conventions used in the following text: the keys of compilation (e.g. *key dtasal),* the names of programs (e.g. *ocesbc med.F90*), subroutines (e.g. *zgr bat ctl* subroutine), parameters of the namelist (e.g. *ln traadv cen2*), and files (e.g. *runoff 1m nomask med.nc*) are written in italic, and the spaces between the words must be filled by underscores.

3 Grid and bathymetry

NEMOMED8 covers the whole Mediterranean Sea plus a buffer zone including a part of the near Atlantic Ocean. It does not cover the Black Sea. The horizontal resolution is 1/8°x1/8°cos(lat). This is equivalent to a range of 9 to 12 km from the north to the south of the model with square meshes. The C grid in Arakawa's classification (Arakawa 1972) is used for the discretization. The five grids T, u, v, f, w describe each box. The NEMOMED8 grid is tilted and stretched at the Gibraltar strait to better follow the SW-NE axis of the real strait and to increase the local resolution up to 6 km. The fig. 3 gives an idea of the (i,j) definition of the grid which leads to this deformation. The Gibraltar strait is represented with a two grid-point wide strait. One can choose the lateral boundary condition on velocity, with the value of shlat in the namelist. With the no-slip boundary condition (shlat=2), the tangential velocity vanishes at the coastline (see [Madec 2008]). The intensity of the water transport at the Gibraltar strait strongly depends on the shlat option.

There are two vertical scales, both with 43 vertical Z-levels with an inhomogeneous distribution: one in the Mediterranean Sea, and one in the Atlantic part, where the bottom is deeper. For the first one, the thickness ranges from 6 m at the surface to 200 m at the bottom with 25 levels in the first 1000 m; the maximum depth is 4100 m; for the second one, the last levels are 300 m thick and the maximum depth is 5650 m. Both vertical distributions share the same 18 first layers above the Gibraltar sill. The depths of the T and W levels are given in tab. 1.

The bathymetry (fig. 1) is based on ETOPO5'x5' data base ([Smith and Sandwell 1997]). One can use a partial cell bathymetry if *key partial steps* is used for the compilation. Then the last level of the model has a variable depth to fit the real bathymetry. It is important to know that isolated ocean grid points are suppressed: thus the bottom level of the model grid can differ from the bathymetry. In NEMOMED8, it is written in the *zgr bat med ctl* subroutine, and in NEMO in the *zgr bat ctl* subroutine.

The type of vertical coordinate is chosen in the namelist, with *ln zco* (z-coordinate, full steps), *ln zps* (z-coordinate, partial steps), or *ln sco* (s or hybrid coordinate, not tested).

4 Boundary conditions

4.1 River runoffs

The river runoffs play an important role in the water budget of the Mediterranean Sea, since the annual mean is 0.14 m/yr ([Ludwig et al. 2009]) to be compared with the net E-P-R (Evaporation minus Precipitation minus Runoff) budget estimated to 0.64 m/yr in [Baschek et al. 2001] (including the Black Sea). In the NEMOMED8 model, the Black Sea is also treated as a river, for its water is much less salty than the Aegean one. The estimation of E. Stanev is a runoff of about 8000 m^3/s, which is much more than any other river of the Mediterranean basin ([Stanev 2000]). Added to the climatological runoffs of 32 rivers taken from the RivDis database for most of them, and which list can be found hereafter, the annual mean of the runoff provided to NEMOMED8 is 0.19 m/yr. The monthly runoffs of the four main rivers, Rhône, Po, Ebro, and Nile (two mouths Rosetta and Damietta, after the Aswan dam), and the Black Sea are presented in tab. 2.

The climatological river runoffs are described in a file called *runoff 1m nomask med.nc*, containing the monthly runoffs of the rivers in mm/s, and an array with 1 at the mouths and 0 elsewhere. The runoff is used in the water budget, after a temporal interpolation between two months depending on the day, and a multiplication by -1. The nrunoff value in the namelist will be discussed in the Ocean tracers section (§5.2).

In coupled mode, the climatological runoffs are still used. The use of a runoff model as TRIP ([Oki and Sud 1998]) between the atmospheric and oceanic models is not yet possible.

There is a second type of river runoffs that can be used with NEMOMED8, which is interannual data ([Beuvier 2008]) (fig. 2). They come from [Ludwig et al. 2009], and are adapted to the 32 rivers. An interannual variation of the Black Sea "runoff" is also introduced thanks to E. Stanev collaboration. The

	gdept (M)	gdepw (M)	e3t (M)	e3w (M)	gdept (A)	gdeptw (A)	e3t (A)	e3w (A)
1	3.13	0.00	6.64	6.27	3.13	0.00	6.64	6.27
2	9.77	6.27	6.64	6.27	9.77	6.27	6.64	6.27
3	17.02	13.17	7.25	6.89	17.02	13.17	7.25	6.89
4	25.09	20.81	8.07	7.64	25.09	20.81	8.07	7.64
5	34.15	29.35	9.06	8.54	34.15	29.35	9.06	8.54
6	44.39	38.98	10.24	9.62	44.39	38.98	10.24	9.62
7	56.06	49.90	11.67	10.92	56.06	49.90	11.67	10.92
8	69.42	62.38	13.37	12.48	69.42	62.38	13.37	12.48
9	84.83	76.72	15.40	14.34	84.83	76.72	15.40	14.34
10	102.65	93.28	17.82	16.56	102.65	93.28	17.82	16.56
11	123.35	112.48	20.70	19.20	123.35	112.48	20.70	19.20
12	147.47	134.82	24.11	22.34	147.47	134.82	24.11	22.34
13	175.60	160.86	28.13	26.04	175.60	160.86	28.13	26.04
14	205.45	191.26	32.85	30.40	208.45	191.26	32.85	30.40
15	246.79	226.75	38.35	35.49	246.79	226.75	38.35	35.49
16	291.51	268.17	44.72	41.42	291.51	268.17	44.72	41.42
17	343.54	316.42	52.04	48.25	343.54	316.42	52.04	48.25
18	403.92	372.49	60.37	56.07	403.92	372.49	60.37	56.07
19	464.56	432.09	66.80	63.11	473.69	437.43	69.77	64.94
20	535.20	498.92	74.55	70.62	553.93	512.30	80.24	74.87
21	613.80	573.48	82.71	78.59	645.69	598.17	91.76	85.87
22	700.73	656.21	91.19	86.92	749.94	696.07	104.25	97.89
23	796.26	747.41	99.88	65.52	867.53	806.89	117.59	110.83
24	900.52	847.29	108.65	104.26	999.14	931.42	131.61	124.53
25	1013.53	955.93	117.37	113.02	1145.22	1070.22	146.08	138.80
26	1135.20	1073.30	125.92	121.67	1305.99	1223.64	160.77	153.42
27	1265.28	1199.20	134.19	130.10	1481.39	1391.75	175.40	168.11
28	1403.44	1333.37	142.06	138.18	1671.11	1574.36	189.72	182.61
29	1549.25	1475.42	149.47	145.83	1874.60	1771.05	203.49	196.69
30	1702.20	1624.86	156.35	152.98	2091.11	1981.16	216.51	210.11
31	1861.76	1781.19	162.67	159.58	2319.74	2203.84	228.62	222.69
32	2027.35	1943.84	168.41	165.62	2559.47	2438.15	239.73	234.31
33	2198.40	2112.23	173.58	171.07	2809.24	2683.04	249.77	244.89
34	2374.33	2286.79	178.19	475.95	3067.99	2937.43	258.74	254.39
35	2554.60	2463.95	182.27	180.29	3334.65	3200.26	266.67	262.83
36	2738.70	2646.20	185.85	184.12	2608.25	3470.51	273.60	270.25
37	2926.16	2832.04	188.99	187.48	3887.86	3747.23	279.61	276.71
38	3116.54	3021.01	191.71	190.40	4172.64	4029.52	284.78	282.29
39	3309.46	3212.71	194.07	192.93	4461.85	4316.60	289.21	287.08
40	3504.57	3406.76	196.10	195.12	4754.82	4607.77	292.97	291.17
41	3701.56	3602.85	197.85	197.00	5050.98	4902.41	296.16	294.63
42	3900.17	3800.68	199.34	198.62	5349.83	5199.97	298.85	297.56
43	4100.16	4000.01	200.61	200.00	5650.94	5500.00	301.11	300.03

Table 1: Vertical mediterranean (M) and atlantic (A) z-coordinates in meters (for the definition of the T and W points see [Madec 2008])

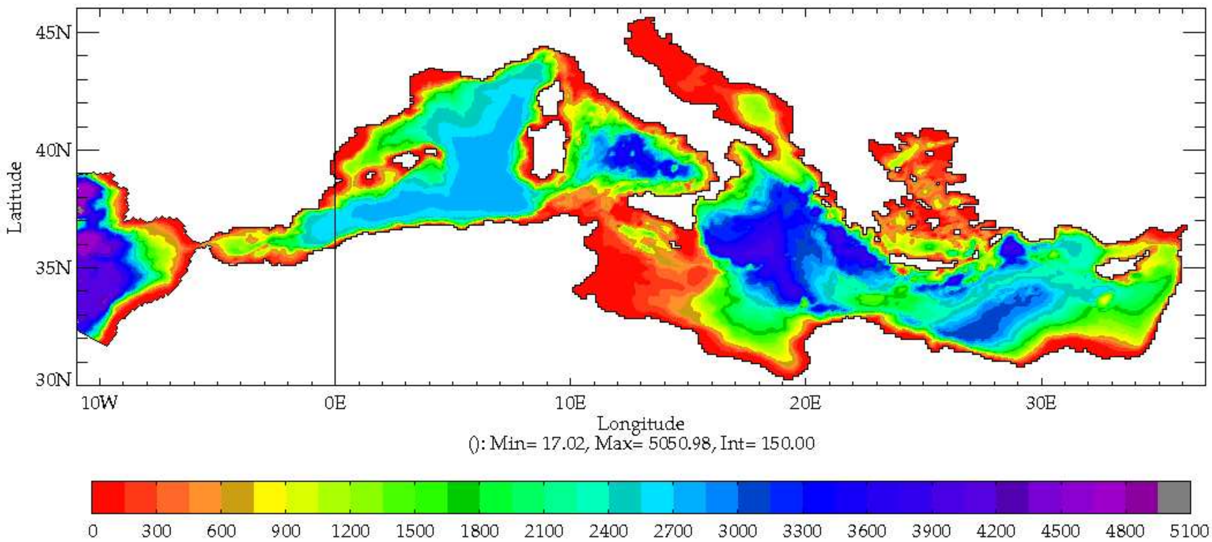

Figure 1: bathymetry of the model

month	1	2	3	4	5	6	7	8	9	10	11	12
Rhône	1885	2046	2036	1846	1887	1830	1389	1149	1168	1392	1911	1862
Po	1225	1313	1586	1610	1914	1836	1199	954	1308	1674	1922	1434
Ebro	697	752	829	692	648	552	251	143	191	319	522	658
Rosetta	455	546	555	542	646	848	867	767	566	510	508	478
Damietta	201	241	245	239	285	374	382	338	249	225	224	211
Black Sea	12570	9569	9260	10221	14403	11120	8029	-2827	4322	5992	3473	10302

Table 2: Monthly runoffs in m^3/s

files read by NEMOMED8 will be *runoff 1m nomask med.aaaa.nc* (year aaaa). To use this possibility of interannual runoffs, one has to compile the code with *key runoff yearly*.

The list of the mouths is the following, with the latitude, longitude, coordinates in the model grid, and discharge in the RivDis database followed if necessary by the new ones according to [Ludwig et al. 2009]:

- Guadalquivir (Spain) : 6,3°W, 36,8°N, i = 56, j = 69, 152 m^3/s;
- Ebro (Spain) : 0,85°W, 40,8°N, i = 112, j = 104, 521 m^3/s then 414 m^3/s;
- Jucar (Spain) : 0,25°W, 39,2°N, i = 103, j = 89, 49 m^3/s then 40 m^3/s;
- Drin (Albany) : 19,6°E, 41,8°N, i = 259, j = 115, 298 m^3/s then 371 m^3/s;
- Vijose (Albany) : 19,3°E, 40,65°N, i = 258, j = 103, 158 m^3/s then 157 m^3/s;
- Mati (Albany) : 19,6°E, 41,7°N, i = 259, j = 114, 25 m^3/s;
- Erzeni (Albany) : 19,4°E, 41,7°N, i = 259, j = 111, 14 m^3/s;
- Shkumbin (Albany) : 19,45°E, 41,05°N, i = 259, j = 108, 59 m^3/s;
- Seman (Albany) : 20°E, 40,78°N, i = 259, j = 107, 60 m^3/s;
- Rhône (France) : 4,9°E, 43,4°N, i = 143, j = 132, 1700 m^3/s then 1725 m^3/s;
- Aliakmon (Greece) : 22,6°E, 40,5°N, i = 286, j = 101, 49 m^3/s then 95 m^3/s;
- Akheloos (Greece) : 21,1°E, 38,3°N, i = 272, j = 80, 110 m^3/s then 113 m^3/s;
- Po (Italy) : 12,5°E, 44,9°N, i = 205, j = 150, 1498 m^3/s then 1555 m^3/s;
- Adige (Italy) : 12,3°E, 45,15°N, i = 204, j = 153, 202 m^3/s then 237 m^3/s;
- Tevere (Italy) : 12,2°E, 41,7°N, i = 202, j = 115, 231 m^3/s then 136 m^3/s;
- Guadiana (Portugal) : 7,4°W, 37,15°N, i = 55, j = 76, 194 m^3/s;
- El Kebir (Algeria) : 6,05°E, 36,9°N, i = 152, j = 65, 0,4 m^3/s then 26 m^3/s;
- Soummam (Algeria) : 5,05°E, 36,8°N, i = 144, j = 65, 6 m^3/s then 29 m^3/s;
- Seybouse (Algeria) : 7,8°E, 36,9°N, i = 144, j = 65, 3 m^3/s then 8 m^3/s;
- Tafna (Algeria) : 1,55°W, 35,3°N, i = 91, j = 49, 6 m^3/s then 9 m^3/s;
- Isser (Algeria) : 3,75°E, 36,8°N, i = 133, j = 65, 7 m^3/s then 6 m^3/s;
- Mazafran (Algeria) : 2,82°E, 36,67°N, i = 126, j = 63, 6 m^3/s then 13 m^3/s;
- Sebaou (Algeria) : 3,85°E, 36,9°N, i = 135, j = 65, 18 m^3/s then 7 m^3/s;
- Cheliff (Algeria) : 0,15°E, 36,05°N, i = 105, j = 56, 27 m^3/s then 85 m^3/s;
- Nile at Rosetta (Egypt) : 30,4°E, 31,4°N, i = 347, j = 13, 607 m^3/s then 792 m^3/s;
- Nile at Damietta (Egypt) : 31,9°E, 31,4°N, i = 359, j = 14, 268 m^3/s then 349 m^3/s;
- Sebou (Morocco) : 6,4°W, 34,2°N, i = 37, j = 56, 62 m^3/s;
- Moulaya (Morocco) : 2,4°W, 35,1°N, i = 85, j = 49, 101 m^3/s then 78 m^3/s;
- Oum Er Rebia (Morocco) : 8,4°W, 33,3°N, i = 20, j = 62, 70 m^3/s;
- Mejerdah (Tunisia) : 10,6°E, 36,8°N, i = 187, j = 67, 19 m^3/s then 78 m^3/s;
- Kouris (Cyprus) : not in RivDis, i = 367, j = 42, 0,7 m^3/s then 2,3 m^3/s;
- Buyuk (Turkey) : 27,11°E, 37,27°N, i = 321, j = 71, 90 m^3/s then 130 m^3/s;
- Seyhan (Turkey) :35,42°E, 36,45°N, i = 390, j = 62, 208 m^3/s then 255 m^3/s;
- The Black Sea: not in RivDis, i = 313, j = 98, 8036 m^3/s then 7696 m^3/s.

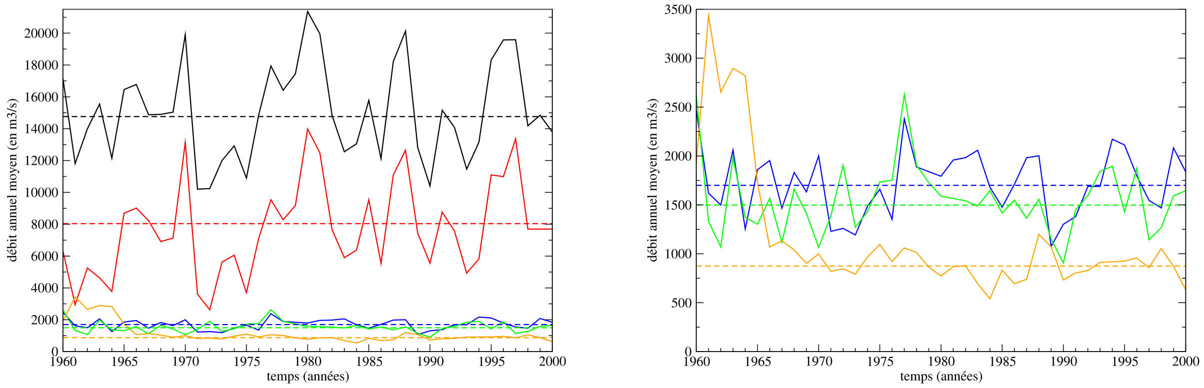

Figure 2: Annual mean runoffs (in m^3/s) of the 33 rivers (black), the Black Sea (red), the Rhône (blue), the Po (green), and the Nile (orange). The lines show the annual means of the climatology previously used (not the mean of the interannual data). The right figure is a zoom of the left one.

4.2 Atlantic buffer zone

We call Atlantic buffer zone the western part of the domain, from 11°W to the Gibraltar strait, where a 3D damping in temperature and salinity can be performed if *key tradmp* is used for the compilation. The aim is to get a realistic circulation through the Gibraltar strait by giving "atlantic" characteristics to the Atlantic side of the strait. The damping must be strong at the western limit of the buffer zone, and less and less when approaching the Gibraltar Strait. With NEMOMED8 we use a coefficient which evolves from 3 days to 100 days (that is $1/3 * 86400$ to $1/100 * 86400$) from 11°W to 7.5°W, and zero elsewhere. A *relax.nc* file is needed which contains the array of the coefficient (in s^{-1}, first level), and another dimension which will be used to change the advection scheme near the Gibraltar strait if the centered scheme is chosen (*ln traadv cen2*=true in the namelist, see §5.2).

The *key dtatem* and *key dtasal* options of compilation must be chosen to read the climatologies in *data 1m potential temperature nomask med.nc* and *data 1m salinity nomask med.nc*. Up to recently we used the Reynaud seasonal climatology ([Reynaud 1998]) in the Atlantic and the MEDATLAS II climatology ([MEDAR/MEDATLAS 2002]) in the Mediterranean.

There is now a possibility to use interannual data of temperature and salinity for the Atlantic buffer zone as it was done in [Beuvier 2008]. They come from a reanalysis of the global ocean done by N. Daget ([Daget et al. 2008]), and are adapted to the NEMOMED8 grid and bathymetry. The files read by NEMOMED8 will be *data 1m potential temperature nomask med.aaaa.nc* and *data 1m salinity nomask med.aaaa.nc* (year aaaa). For that one has to compile the code with *key dtasal yearly* and *key dtatem yearly*.

4.3 Surface relaxation

There is no default surface relaxation in NEMOMED8. One can choose an SST relaxation with *key dtasst*, an SSS relaxation with *key dtasss*, but only in forced mode.

The aim of the SST relaxation is to apply a first order feedback of the ocean surface on the air-sea fluxes. The model will read the daily SST in *sst.Yaaaa.Mmm.med.nc* with aaaa and mm respectively the year and month, and the SST in Celsius degrees (see §8.4 for the description of the file). The relaxation coefficient is written in *ocesbc med.F90* and is by default equal to -40 $W.m^2.K^{-1}$, which is equivalent to an 8-day relaxation time.

There is the possibility to use a 2D monthly array for the SST relaxation coefficient, with *key fbtdta*, but this option has not been tested. The file is called *fbtdta med 1m mask.nc*.

If one chooses *key dtasss* a correction method will be applied, using the monthly climatological value of SSS if *key dtasal* is used for the compilation, 0 if not. The relaxation coefficient is written in *ocesbc med.F90*, and is equal to$-40 * rauw/(rau0 * rcp)$ (again equivalent to an 8-day relaxation time), with:

- rauw=1000 kg/m^3 : density of pure water
- rau0=1020 kg/m^3: volumic mass of reference
- rcp=4000 : ocean specific heat

Note that the SSS coefficient of relaxation is 0 at the mouths of the rivers.

4.4 Flux correction

The use of a water or heat flux correction is less restricting for the system than a relaxation. If *key erp array* is chosen, then it's not a relaxation but a correction of the water flux which will be done. The correction value is fixed for the whole basin with a monthly value, set in the namelist (namerp section). It is possible to introduce the same option for a heat flux correction, it will use *key qrp array*, and it was done in OPAMED8. The aim of these options is to use a flux correction which is not too restricting for the system. For example, as correction terms, one can use the average of the relaxation value of an experiment previously done with the same surface fluxes.

4.5 Free surface or rigid lid

These options are chosen respectively with *key dynspg flt* (filtered free surface) or *key dynspg rl* (rigid lid) for the compilation. There are also *key dynspg exp* (explicit free surface) and *key dynspg ts* (split-explicit free surface), which have not been tested with NEMOMED8.

When the filtered free surface is chosen, the volume of the Mediterranean Sea is not conserved, given the loss of water induced by the surface evaporation. In order to conserve the volume, we use a method written by K. Beranger, which works as follows: at each time step the evaporated water over the whole basin is redistributed in the Atlantic buffer zone, with a weight which is stronger with the distance to Gibraltar; a slope is then artificially created in the buffer zone. The weights used in the example vary from 1 at the Atlantic western limit to 0.03 near Gibraltar, that is $3 * 86400 * resto(i, j)$ where resto is the array used for the damping in the Atlantic buffer zone (cf §4.2).

There is another method of volume conservation activated with *ln fwb*=true in the namelist. At the end of a year of run, it computes the mean of the sea surface height divided by one year in seconds (to get mm/s); this value is added at each timestep to the E-P budget, so that there is no loss of volume. The file *EMPave old.dat* is used to keep the values from one launch to another. The model reads *EMPave old.dat* when it begins a period (kt=nit000), and writes *EMPave.dat* at the end (kt=nitend). Thus to begin a run one must provide a first file, with one line, for example:

1960 0.0000000000000000E+00 0.0000000000000000E+00

This option is not recommended in coupled mode because it is a flux correction.

4.6 Forced mode

NEMOMED8 works only in flux mode, that is not in bulk mode (for the moment). The model needs the wind stress in N/m^2, the solar flux in W/m^2, the net heat flux in W/m^2, the water budget E-P (evaporation minus precipitation) in mm/s with the evaporation positive, and the runoff in mm/s and positive.

The forced mode is the default mode, there is no specific key of compilation to choose.

The model works with daily fluxes, organised in monthly files, each one with its own number of days in the real calendar. The inputs are detailed below, one will find a "ncdump" type formulation in §8.4.

4.6.1 Wind stress

Two files *taux.Yaaaa.Mmm.med.nc* and *tauy.Yaaaa.Mmm.med.nc* (year aaaa and month mm) are needed, with the stress in N/m^2. They must be directed on the direction of the grid, which is tilted in the Gibraltar strait. When the fields are interpolated, each component taux and tauy must be interpolated on the two grids u and v, and a rotation must be added, using the ascii file i.j.cosu.sinu.cosv.sinv: 63040 lines with i j cosu sinu cosv sinv, and the following formulas:

taux=taux u*cosu + tauy u*sinu

tauy=tauy v*cosv - taux v*sinv

4.6.2 Other fluxes

The file *flx.Yaaaa.Mmm.med.nc* contains the net surface heat flux in W/m^2 (solar + infrared + turbulent), the solar flux in W/m^2, and the net water budget E-P in mm/s.

4.7 Coupled mode

The coupled mode allows the oceanic model NEMOMED8 to exchange surface fluxes with an atmospheric model, ARPEGE-Climate, ALADIN-Climate or LMDZ for the moment. The OASIS coupler of the CERFACS ([Valcke 2006]) is in charge of the communication between the models and of the interpolation of the fields from the source grid to the target grid. The coupling frequency is fixed at one day, but this can be changed (test "IF (MOD((kt-1)*rdttra(1),86400) == 0) THEN" in *ocesbc med.F90*).

The coupled mode is set for the OASIS3 coupler with the MPI communication. The *key coupled* and *key oasis3* options must be chosen for the compilation.

The number of exchanged fields and their name (see below) for the namcouple are set in *cpl oasis3.F90.couple*, as well as the name of the model in the coupled system ("opam").

4.7.1 Received fields

- the wind stress is received in four variables (in N/m^2), each direction being interpolated on the u and v grids of NEMOMED8: SOZOXMED and SOZOVMED for the zonal direction, SOMEUMED and SOMEYMED for the meridian one; then a rotation is performed to take into account the distorsion of the grid at the Gibraltar Strait, and the two wind stress taux and tauy are finally computed (cf 4.6.1);
- the non solar heat flux SONSHMED in W/m^2(infrared + turbulent); warning: it is different from the forced mode where the net heat flux is read;
- the solar heat flux SOSHFMED in W/m^2;
- the water flux SOWAFMED E-P in mm/s with E>0.

4.7.2 Sent fields

- the SST SOSSTMED in °K;
- the ice field SOICEMED which is zero everywhere since there is no ice model in the system;
- the albedo SOALBMED which is constant and equal to 0.065 on the sea mask;
- a second SST SOJMUMED in °K, equal to SOSSTMED, which can be used for a SUBGRID treatment in OASIS3.

Note: when the atmospheric model is global, like ARPEGE-Climate, one must provide the data outside the NEMOMED8 grid: it is the role of the FILLING option of OASIS3.

5 Ocean tracers

Not many things are changed in NEMOMED8 compared to NEMO. This concerns the damping in the Atlantic buffer zone, and the tracers advection near the rivers mouths.

5.1 Tracers damping

See §4.2

5.2 Tracers advection and lateral mixing trend

There is a specific treatment of the advection trend if the second order centered scheme is chosen with *ln traadv cen2*=true in the namelist. A mixed centered and upstream scheme is used around Gibraltar (i from 54 to 60 and j from 55 to 66), and at the river mouths in the five first levels. The coefficients are set respectively to 1, 1, 1, 0.5, 0.25 from the first to the fifth level (in *flxrnf MED8.h90*).

In term of lateral diffusion, we must specifiy that all the tests performed with the bilaplacian option (*ln traldf bilap*=true in the namelist) have produced odd results, with many oscillations of the tracers through the whole column.

The recommended options are *ln traldf lap*=true and *ln traldf iso*=true.

6 Diagnostics

The standard outputs of NEMO have been modified for NEMOMED8. First, in the case of netcdf format, the 2D fields have been separated from the 3D fields, to allow the outputs at different timesteps. Secondly, specific outputs have been added, which where computed in OPAMED8, like transports through predefined sections.

The output format is netcdf by default. It can be changed to dimg (specific OPA format), with *key dimgout* for the compilation.

We present here the outputs of a monoprocessor run.

6.1 dimg format

The frequency of the output is nwrite, set in the namelist.

The diagnostics are separated in the following categories: T, S, U, V, 2D, W, KZ, and the names of the files are cexper var aaaammjj.dimgproc, with cexper the experience name given in the namelist, var the category, and aaaammjj the day corresponding of the moment of writing in the model run. The outputs are instantaneous if the *key diainstant* is chosen. The details are in *diawri dimg med.h90*.

6.2 2D outputs in netcdf

They are written at the daily frequency, averaged on the day if *key diainstant* is not used in the compilation.

The frequency is set in *diawri med.F90*, not in the namelist where the nwrite frequency only concerns the 3D diagnostics.

The name of the output is *cexper 1d aaaammjj1 aaaammjj2 2D.nc*, aaaammjj1 and aaaammjj2 the dates of beginning and end of the run. Thus for a one month run all the daily means will be written in the same file.

The list of the diagnostic is the following with their names in the .nc file:

- sea surface temperature (sosstsst) in °C,
- sea surface salinity (sosaline) in psu,
- sea surface elevation (sossheig) if not in rigid lid case in m,
- barotropic stream function (sobarstf) if rigid lid case in m^3/s,
- net upward water flux (sowaflup) in mm/s, contribution to the sea level (E-P-R+correction or surface water flux damping if necessary+contribution of the internal damping if *key tradmp* and free surface),
- runoffs (sorunoff) in mm/s,
- net upward water flux (sowaflcd) in mm/s, contribution to the salinity (E-P-R+correction or surface water flux damping if necessary),
- surface salt flux (sosalflx) sowaflcd*SSS,

- net heat flux (sohefldo) in W/m^2 (including a surface heat flux damping if necessary),
- solar radiation (soshfldo) in W/m^2,
- mixed layer depth (somxl010) in m with a density criterion of 0.01kg/m^2 (in *zdfmxl.F90*),
- turbocline depth (somixhgt) in m with a KZ criterion of 5.10^{-4},
- surface heat flux damping (sohefldp) in W/m^2,
- surface water flux damping (sowafldp) in mm/s,
- surface salt flux damping (sosalfldp) sowafldp*sosaline,
- bowl index (sobowlin) in W-point, number of levels in the mixed layer,
- thermocline depth (sothedep) in m if *key diahth*, defined as the depth of the strongest vertical temperature gradient between two levels,
- depth of the 20°C isotherm (so20chgt) in m if *key diahth*,
- depth of the 28°C isotherm (so28chgt) in m if *key diahth*,
- heat content 300 m (sohtc300) in W if *key diahth*,
- sss used for surface relaxation (sossscli) in psu if *key dtasss*,
- sst used for surface relaxation (sosstcli) in °C if *key dtasst*,
- surface pressure (sogpsm) if *key diaspr med* or *key diainstant*,
- barotropic component of the sea level (sohbar) if *key diaspr med* or *key diainstant*,
- baroclinic dynamic height (sohdyn) if *key diaspr med* or *key diainstant*,
- depth of the mixed layer base (somxlb) in m if *key mxlb* (in *diamxl med.F90*, another way to compute the mixed layer base, not tested, needs to be read before).

6.3 3D outputs

They are separated in grid T, grid U, grid V, and grid W types:

- grid T: potential temperature (votemper in °C) and salinity (vosaline in psu); the model can also write the potential density (vorhopot in kg/m^3) if *key diawri rhop* is used;
- grid U: zonal current (vozocrtx in m/s) and wind stress (sozotaux in N/m^2);
- grid V: meridional current (vomecrty in m/s) and wind stress (sometauy in N/m^2);
- grid W: vertical current (vovecrtz in m/s), vertical and lateral eddy diffusivity (respectively votkeavt and soleahtw in m^2/s, the latter if *key traldf c2d*).

The frequency of the outputs is nwrite, or $(nitend - nit000 + 1) * zdt$ if $nwrite = nitend$. The latter possibility has been set for monthly runs: the outputs will be directly the monthly means of the fields, even if one uses a "true" calendar.

The names of the outputs are *cexper freq aaaammjj1 aaaammjj2 grid var.nc*, with freq set to 1d, 5d, 1m or 1y respectively for daily, five days, monthly, annual outputs, or CUn with n number of timesteps.

More details can be found in *diawri med.F90*.

6.4 Transports

As in OPAMED8, *key transport* activates the computing of the transport through predefined sections chosen in the whole basin.

The frequency of writing is nwdct in the namelist. The transports are averaged over the same period. To get instantaneous values, one must *modify diadct.F90*.

The number of sections, and the number of classes in temperature, density and salinity for additive diagnostics are set in *par MED R8.h90*. Consequently a new compilation is necessary in case of any modification.

The sections are described in *initransp.h90* (fig. 3). For each section, one can choose if the density, temperature and salinity diagnostics will be computed with lmstrpond equal to true (if false, only the transport will be computed), and the classes of density, temperature or salinity, if a specific current is scrutated. The number of classes is defined by inbclass which is the number of classes plus one. The following diagnostics are written in the file DCT.diagnostic, they are averaged on the nwdct period, for each predefined class (or all points of the section if no class is chosen):

- positive transport in m^3/s through the vertical section;
- negative transport;
- density weighted by the transport, separated in the positive and negative directions, through the vertical section (if lmstrpond=true);
- idem for temperature;
- idem for salinity.

Note: to recover a density, a temperature or a salinity in the positive or negative direction, one must divide the read value by the positive or negative transport.

6.5 Other diagnostics

- if *key floats*, trajectories of floats are computed and written in trajec floats; if *key proflo* is also used for the compilation, profiles of temperature, salinity, density, and velocities are computed at the floats positions, and written in fort.86 (numprofl in *med oce.F90*) at the rwriprofl frequency; this option is not fully accessible, a namflo section must still be added to the namelist;
- if *key diaspr med* and *key ps eg*:
  - si *key dynspg rl* (rigid lid) computation of an estimation of the barotropic component of the sea level (hbar variable), and an hydrostatic pressure anomaly converted in a sea level anomaly (hdyn variable);
  - computation of the estimated surface pressure with an E. Greiner method (gpsm variable, computed as an elevation which average is zeo plus a reference value, cf. *sfc prg* subroutine in *presmod.F90*);
- if *key mooring*:
  - the maximum number of mooring points is defined in *med oce.F90*, their description is written in the position.moor file;
  - vertical profiles of current, temperature, salinity and kz are computed every nwmoor timesteps (in namelist), and written in cmoor.mooring file, where cmoor is the name of the mooring read in position.moor;
- if *key xbt*: idem as *key mooring* but with sections, described in a position.sect file, and results in csect.section files where csect is the name of the section in the position.sect file.

6.6 Standard output

The standard output of the model is written in the *ocean med.output* file.

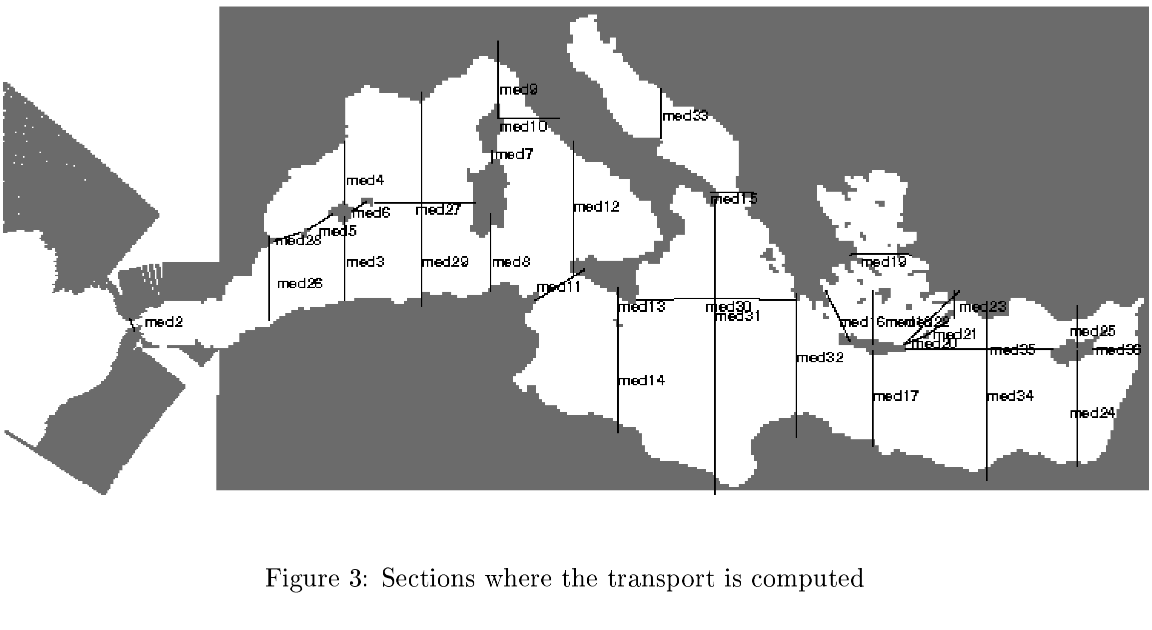

Figure 3: Sections where the transport is computed

7 Communication with NEMO-ORCA2 through the Gibraltar strait

The european CIRCE project initiated a new tri-coupled configuration, with which a 100-year scenario must be performed: ARPEGE-Climate - NEMO-ORCA2 - NEMOMED8. Instead of giving to ARPEGE-Climate climatological data of SST on the whole globe around the Mediterranean Sea, there is the possibility to add the NEMO-ORCA2 global ocean model in the system. Then ARPEGE-Climate can receive the SST of NEMOMED8 on the Mediterranean Sea and of NEMO-ORCA2 everywhere else. The two ocean models communicate at the Gibraltar strait, when the *key cpl orca2* compilation option is chosen for NEMOMED8, and *key cpl med* for NEMO-ORCA2.

7.1 From NEMO-ORCA2 to NEMOMED8

Considering that NEMOMED8 works with an Atlantic buffer zone, the influence of the NEMO-ORCA2 global ocean model will come through this part of the domain. The chosen method is to modify every day the climatological data used for the T and S 3D-damping with the characteristics of the same domain in NEMO-ORCA2 (10 points): the profiles of temperature and salinity are computed each day by NEMO-ORCA2 and written in the *profil buffer temp.dat* and *profil buffer sal.dat* files (one profile for the 10 points). NEMOMED8 reads these files, computes anomaly profiles to the climatological ones (one profile for the whole buffer zone), and adds these anomalies to the 3D-climatologies towards which the damping is performed. The use of an unique 1D-profile has been decided as the spatial variability of the daily anomalies is weak, and as the ORCA2 grid contains only 10 grid points over the NEMOMED8 Atlantic buffer zone. Thus the daily variability of the near Atlantic is taken into account by NEMOMED8, allowing the evolution through a scenario for example, but no heat nor salt transports are imposed at the Gibraltar Strait.

The following files are needed:

- *profil buffer temp.dat* and *profil buffer sal.dat*: vertical 1D-profiles of T and S on 31 levels averaged on the Atlantic buffer domain of the ORCA2 grid;
- interpolz: data to perform the interpolation between the 31 vertical levels of ORCA2 towards the 43 vertical levels of NEMOMED8 (integer iadress(43,2) and real zweights(43,2), respectively the two levels of ORCA2 and associated weights above and under a NEMOMED8 level);
- *profilclim buffer temp.nc* and *profilclim buffer sal.nc*: vertical monthly profiles of T and S on 43 levels of the climatology [Reynaud 1998].

7.2 From NEMOMED8 to NEMO-ORCA2

The ORCA2 grid is closed at the Gibraltar strait in NEMO-v2, and the communication between the Mediterranean Sea and the Atlantic uses the Cross-Land-Advection parameterization (n cla=1 in the namelist): it allows to assess the Mediterranean Outflow Water characteristics (T, S) in the Atlantic part of the model with respect to the characteristics of the Mediterranean deep waters, the Atlantic surface waters and the Atlantic sub-surface waters. In the case of using the NEMOMED8 model for the Mediterranean basin, the variables depending on the Mediterranean Sea part of the NEMO-ORCA2 model are replaced by those of the regional model:

1. the volume of the Gibraltar outflow transport (by default set to 0.8 Sv in NEMO-ORCA2) is computed in the *transport* subroutine of NEMOMED8 and through the "med2" section which corresponds to the Gibraltar Strait (cf. § 6.4); it is a negative value because it comes out the Mediterranean Sea, in m^3/s; consequently the value of this transport can freely vary every day;
2. the heat and salt transports of the deep Mediterranean layers that enters the wall, are computed in the *transport* subroutine as well (if lmstrpond=true, cf. §6.4), and given in °C and PSU;
3. the E-P-R water loss by the NEMOMED8 ocean surface; in practical it is estimated in NEMO-ORCA2 by modifying E-P-R of the ORCA2 Mediterranean to take into account the difference of surfaces and climatological runoffs of the two Mediterranean Seas (one of each model); this E-P-R is added to the Gibraltar outflow in order to compute the Gibraltar Strait inflow.

For this method to run, the *key transport* must be used for the compilation of NEMOMED8: it will write in a *DCT.med2* ASCII file the three values described in the points 1 and 2 of this chapter 7.2, at the nwdct frequency (cf §6.4).

8 Input of the model, forced or coupled mode

8.1 The namelist

The namelist contains all the options which don't need a new compilation of the model. It is nearly the same as the NEMO's one: a few parts have been added, especially for the diagnostics. One important difference is the name: *namelist med*. An example of this file will be found in §10.

8.2 Grid and bathymetry

The Mediterranean version needs the following imputs:

- *bathy meter med.nc*: at each point the depth in meters; not used in full steps configuration, but must be present;
- *bathy level med*, describing the bathymetry in model levels, in ascii format;
- the vertical levels are described in the *coordinates med.z.nc* file, with different arrays for the Mediterranean and the Atlantic;
- *coordinates med.nc*: longitudes and latitudes of the points, and dimensions of the meshes in the x and y directions;
- the *nmedatl.nc* file contains an array with 1 in the Atlantic box and 0 elsewhere: it allows the discrimination between the two vertical scales.

8.3 Restart

If there is one (*ln rstart*=true in the namelist), it is named *restart med.nc*, and is nearly the same as the NEMO's restart, without the fields concerning the sea ice.

If not (*ln rstart*=false) then the initial condition is the T and S climatology, and the ocean at rest.

We recommend to launch the model in summer, to avoid the strong winter fluxes at the beginning.

8.4 Climatologies and forcings

In case of forced mode, the surface forcings have been described in §4.6. One will find below the description of the files for the SST, wind stress and fluxes, because the user may need to produce them. Note that the time counter dimension must be "unlimited".

The runoffs are described in §4.1.

The Atlantic buffer zone needs the climatologies and a *relax.nc* file as described in §4.2.

netcdf sst.Y1960.M08.med {

dimensions:

- x = 394 ;
- y = 160 ;
- deptht = 43 ;
- time counter = UNLIMITED ; // (31 currently)

variables:

double nav lon(y, x) ;

- nav lon:units = "degrees east" ;

- nav lon:long name = "Longitude" ;
- nav lon:nav model = "Default grid" ;

double nav lat(y, x) ;

- nav lat:units = "degrees north" ;
- nav lat:long name = "Latitude" ;
- nav lat:nav model = "Default grid" ;

double deptht(deptht) ;

- deptht:units = "meters" ;
- deptht:long name = "Depth" ;
- deptht:nav model = "Default grid" ;

double time counter(time counter) ;

- time counter:units = "seconds since 0000-12-15 00:00:00" ;
- time counter:calendar = "noleap" ;
- time counter:title = "Time" ;
- time counter:long name = "Time axis" ;
- time counter:time origin = "0000-DEC-15 00:00:00" ;

double sst(time counter, y, x) ;

- sst:units = "deg C" ; sst:long name = "sst" ;

}
netcdf taux.Y1960.M08.med {
dimensions:

- x = 394 ;
- y = 160 ;
- deptht = 43 ;
- time counter = UNLIMITED ; // (31 currently)

variables:
double nav lon(y, x) ;

- nav lon:units = "degrees east" ;
- nav lon:long name = "Longitude" ;
- nav lon:nav model = "Default grid" ;

double nav lat(y, x) ;

- nav lat:units = "degrees north" ;
- nav lat:long name = "Latitude" ;
- nav lat:nav model = "Default grid" ;

double deptht(deptht) ;

- deptht:units = "meters" ;
- deptht:long name = "Depth" ;
- deptht:nav model = "Default grid" ;

double time counter(time counter) ;

- time counter:units = "seconds since 0000-12-15 00:00:00" ;
- time counter:calendar = "noleap" ;
- time counter:title = "Time" ;
- time counter:long name = "Time axis" ;
- time counter:time origin = "0000-DEC-15 00:00:00" ;

double sozotaux(time counter, y, x) ;

- sozotaux:units = "N/m2" ;
- sozotaux:long name = "sozotaux" ;

}
netcdf flx.Y1960.M08.med {
dimensions:

- x = 394 ;
- y = 160 ;
- deptht = 43 ;
- time counter = UNLIMITED ; // (31 currently)

variables:
double nav lon(y, x) ;

- nav lon:units = "degrees east" ;
- nav lon:long name = "Longitude" ;
- nav lon:nav model = "Default grid" ;

double nav lat(y, x) ;

- nav lat:units = "degrees north" ;
- nav lat:long name = "Latitude" ;
- nav lat:nav model = "Default grid" ;

double deptht(deptht) ;

- deptht:units = "meters" ;
- deptht:long name = "Depth" ;
- deptht:nav model = "Default grid" ;

double time counter(time counter) ;

- time counter:units = "seconds since 0000-12-15 00:00:00" ;
- time counter:calendar = "noleap" ;
- time counter:title = "Time" ;
- time counter:long name = "Time axis" ;
- time counter:time origin = "0000-DEC-15 00:00:00" ;

double soshfldo(time counter, y, x) ;

- soshfldo:units = "W/m2" ;
- soshfldo:long name = "solar radiations: daily DA9 for 1/8 MED" ;

double sohefldo(time counter, y, x) ;

- sohefldo:units = "W/m2" ;
- sohefldo:long name = "total fluxes: daily DA9 for 1/8 MED" ;

double sowaflup(time counter, y, x) ;

- sowaflup:units = "kg/m2/s" ;
- sowaflup:long name = "EMP: daily DA9 for 1/8 MED" ;

}

9 Compilation of NEMOMED8

The NEMOMED8 model is a new configuration of NEMO-OPA. There is a *MED SRC* directory under ~/NEMO/modipsl/modeles/NEMO. The original routines of OPA SRC are modified to add the calls of the new subroutines if *key med* and *key med 8* are used for the compilation. A new file *par MED R8.h90* is created with the dimensions of the grid and a few other parameters. There is also a NEMOMED8 directory under ~/NEMO/modipsl/config.

9.1 New keys of compilation

The new keys of compilation added for NEMOMED8 are the followings:

- *key med*: Mediterranean version
- *key med 8*: 1/8° version
- *key erp array*: a monthly array for the correction of the water flux, given in the namelist (cf. 4.4)
- *key runoff yearly*: interannual runoffs (cf. 4.1)
- *key ps eg*: surface pressure (cf. 6.5)
- *key diaspr med*: 2D diagnostics (cf. 6.2 and 6.5)
- *key diawri rhop*: gives the density as a 3D output in the grid T file
- *key transport*: computation of the transports (cf. 6.4)
- *key MOY SST*, *key MOY SSS*: will use an averaged relaxation term on a square of n points
- *key cpl orca2*: to communicate with NEMO-ORCA2 (cf. 7)
- *key mxlb*: diagnostic of the mixed layer depth which pertinence is still to evaluate

- *key zmedatl*: something to do with the moorings
- *key xbt*: gives xbt type information for moorings
- *key dtatem yearly*, *key dtasal yearly*: interannual data of temperature and salinity for the Atlantic buffer zone (cf. 4.2)
- *key fbtdta*: 2D monthly array for the SST relaxation coefficient (cf. 4.3)
- *key diagap*: computes means of temperature and salinity and writes in a diagap file, to be read and tested

9.2 The compilation step-by-step

One can prepare the compilation by the following steps:

- modify ~/NEMO/modipsl/config/NEMOMED8/scripts/BB make.ldef with the chosen keys
- cd ~/NEMO/modipsl/config
- ../modeles/UTIL/fait config NEMOMED8
- cd ../modeles/NEMO
- ../UTIL/fait AA make
- cd ../../util
- ./ins make -t sx8tori for the NEC-SX8 computer

Note that to prepare an ORCA2 LIM configuration, the steps are the same when one replaces NEMOMED8 by ORCA2 LIM.

Then for the compilation:

- cd ~/NEMO/modipsl/config/NEMOMED8
- qsub submake for a forced mode or submake couple for a coupled mode

The ~/NEMO/modipsl/bin/opa binary is created.

10 Example of run: modelling the Mediterranean Sea over the last 40 years using dynamical downscaling of ERA40 and interannual hydrological forcings

As an example of a NEMOMED8 run, we show here the results of a 40 years modelisation of the Mediterranean Sea, with the model forced by atmospheric fluxes computed by the stretched version of ARPEGE-Climate whose large scales have been driven by ERA40 (also called ARPERA dataset, [Herrmann et Somot 2008]). This experiment is more detailed in [Beuvier 2008].

This run is performed in forced mode, with free surface, and partial cells. The compilation keys are the followings: *key vectopt loop key vectopt memory key ldfslp key dynspg flt key traldf c2d key dynldf c2d key dtatem key dtasal key tradmp key zdftke key med key med 8 key diaspr med key ps eg key transport key dtasst key erp array key partial steps*

The run follows 15 years of spin-up, the 5 first years with a 3D damping in T and S to the climatology.

The SSS correction (*key erp array*) is an average of the SSS relaxation term of a similar experiment but with SSS relaxation. The annual mean of the array is equal to +0.2 mm/day.

The atmospheric fluxes result from a dynamical downscaling of ERA40 with ARPEGE-Climate, in its mediash configuration (stretched grid, centered on the Tyrrhenian Sea, resolution of 50 km on the Mediterranean basin). The atmospheric parameters and the fluxes resulting from this simulation have been compared with observations (buoys) and the litterature in [Colin 2006], showing a good concordance with both.

The SST used for the relaxation (*key dtasst*) is the ERA40 one, which was used for the ARPEGE-Climate experiment.

The interannual runoffs have been prepared with [Ludwig et al. 2009], and adapted to the river mouths of the model. The monthly cycles are unchanged, only the interannual variability has been modified (cf §4.1 and fig. 2).

The interannual evolution of the Atlantic buffer zone is a mixing of the climatology and a reanalysis of the global ocean with OPA8.2 on the ORCA2 grid ([Daget et al. 2008]): each month the climatological T and S 3D-field is modified with the mean anomaly profile (one over the whole zone) resulting from the reanalysis (cf. § 4.2).

The flux budgets are presented in table 3. The water budget is practically perfectly balanced (99,6%). The values of the inflow, outflow and net flow at the Gibraltar strait are in good agreement with the litterature. The water inflow and outflow are respectively estimated at: +0,81 Sv and -0,76 Sv in [Baschek et al. 2001], with a margin of error of +/-0,07 Sv on these estimates, +0,92 Sv and -0,88 Sv in [Bryden and Kinder 1991], +0,72 +/-0,16 Sv and -0,68 +/-0,15 Sv in [Bryden 1994], +0,78 Sv and -0,68 Sv in [Tsimplis and Bryden 2000], +1,01 Sv and -0,97 Sv in [Candela 2001]. Thus, the water fluxes simulated by NEMOMED8 at the Gibraltar strait seems to be realistic, as well for the inflow and outflow as for the net flow.

The salt budget is also well balanced (92%). Besides, a part of the missing 8% may be attributed to the non-linearities included in the estimation of the salt fluxes through the Gibraltar strait: in fact, we use daily values in order to obtain these estimates, which does not take into account the intra-daily scale.

On the other hand, the heat budget is far to be balanced. Indeed, the evolution of the heat content of the Mediterannean Sea over the 40 years of the simulation accounts only for 17% of the sum of the heat fluxes at the surface and through the Gibraltar strait. One can notice that our surface heat flux is slightly too small comparing to the -7 +/-3 W/m² given by [Béthoux 1979], but we can here ask the question whether NEMOMED8 is conservative.

Then a comparison (fig. 4, fig. 5 and fig. 6) has been done with the study of [Rixen 2005] where a climatology of the Mediterranean basin is presented for heat and salt contents of different layers, computed with the available observations. The given correlations are computed after removing the trends. The evolution of the upper layer in our simulation is very near to this climatology, especially in temperature, with a significative correlation of 0.69: it was expected thanks to the SST relaxation. In salinity it is true in the ten first years, then the model doesn't follow the slow increase of the observations all along the 40 years. In the intermediate layer the model follows the observations in T and S, but with a positive bias already present at the beginning of the simulation. The correlation is significative only for the temperature and is equal to 0.66. In the bottom layer, the salinity follows the observations, but with less variability. The temperature follows a stronger warming up than the climatology. For this layer, the correlation is significative for both temperature and salinity, respectively equal to 0.54 and 0.43.

The Eastern Mediterranean Transient event is reproduced by this simulation (not shown), better than the former OPAMED8 model, with outflow of dense waters in the Eastern basin. In 1993, the formation rate of water denser than 29.2 kg/m^3 (respectively 29.3 kg/m^3) is equal to 1.2 Sv (resp. 0.5 Sv), and between 1983 and 1993 the averaged rate is equal to 0.3 Sv (resp. 0.1 Sv). These values are in the same order as in [Lascaratos 1999], even if the density is still not strong enough to reach the bottom of the Eastern basin.

We can conclude this short report of a NEMOMED8 simulation by giving the *namelist med*:

!> >
! OPA namelist : model option and parameter input
! ———-
!> >
!
!————————————————————
! namrun parameters of the run
!————————————————————
! no job number
! cexper experience name for vairmer format
! *ln rstart* boolean term for restart (true or false)
! nrstdt control of the restart timestep:
! = 0 ???

! = 1 ???
! = 2 ???
! nit000 number of the first time step
! nitend number of the last time step
! ndate0 initial calendar date aammjj
! nleapy Leap year calendar (0/1)
! ninist initial state output flag (0/1)
! nstock frequency of restart file
! nwrite frequency of OUTPUT file
! nrunoff = 0 no, 1 runoff, 2 runoff+river mouth ups adv
!
! CAUTION: for usual run scripts, logical value of
! ******* *ln rstart* must be .true. or .false.
! and NOT .TRUE. or .FALSE.
&namrun
no = NUMERO DE RUN
cexper = "NM8-atl-fl"
ln rstart = .LRSTAR.
nrstdt = NRSTDT
nit000 = NIT000
nitend = NITEND
ndate0 = 19600801
nleapy = 1
ninist = 0
nstock = 720
nwrite = 72
nrunoff = 2
/
!————————————————————————————
! nam ctl Control prints & Benchmark
!————————————————————————————
! *ln ctl* trends control print (expensive!)
! nprint level of print (0 no print)
! nictls start i indice to make the control SUM (very usefull to compare mono-
! nictle end i indice to make the control SUM (-versus multi processor runs)
! njctls start j indice to make the control SUM (very usefull to compare mono-
! njctle end j indice to make the control SUM (-versus multi processor runs)
! nisplt number of processors following i
! njsplt number of processors following j
! nbench Bench parameter (0/1): CAUTION it must be zero except for bench
! for which we don't care about physical meaning of the results
! nbit cmp bit comparison mode parameter (0/1): enables bit comparison between
! single and multiple processor runs.
&namctl
ln ctl = .false.
nprint = 1
nictls = 0
nictle = 0
njctls = 0
njctle = 0
isplt = 1
jsplt = 1
nbench = 0
nbit cmp = 0
/
!————————————————————————————

! nam mpp Massively Parallel Processing
!————————————————————————
! c mpi send mpi send/recieve type
! = 'S' : standard blocking send
! = 'B' : buffer blocking send
! = 'I' : immediate non-blocking send
&nam mpp
c mpi send = 'S'
/
!————————————————————————
! nam zgr vertical coordinate
!————————————————————————
! *ln zco z-coordinate* - full steps (T/F)
! *ln zps z-coordinate* - partial steps (T/F)
! *ln sco s-* or hybrid z-s-coordinate (T/F)
&nam zgr
ln zco = .false.
ln zps = .true.
ln sco = .false.
/
!————————————————————————
! nam zgr sco s-coordinate or hybrid z-s-coordinate
!————————————————————————
! sbot min minimum depth of s-bottom surface (>0) (m)
! sbot max maximum depth of s-bottom surface (= ocean depth) (>0) (m)
! theta surface control parameter (0<=theta<=20)
! thetb bottom control parameter (0<=thetb<= 1)
! r max maximum cut-off r-value allowed (0<r max<1)
&nam zgr sco
sbot min = 300.
sbot max = 5250.
theta = 6.0
thetb = 0.75
r max = 0.15
/
!————————————————————————
! nam traadv advection scheme for tracer (option not control by CPP keys)
!————————————————————————
! *ln traadv cen2* 2nd order centered scheme (default T)
! *ln traadv tvd* TVD scheme (default F)
! *ln traadv muscl* MUSCL scheme (default F)
! *ln traadv muscl2* MUSCL2 scheme (default F)
! *ln traadv ubs* UBS scheme (default F)
&nam traadv
ln traadv cen2 = .false.
ln traadv tvd = .true.
ln traadv muscl = .false.
ln traadv muscl2 = .false.
ln traadv ubs = .false.
/
!————————————————————————
! nam traldf lateral diffusion scheme for tracer (option not control by CPP keys)
!————————————————————————
! Type of the operator :
! *ln traldf lap* laplacian operator (default T)
! *ln traldf bilap* bilaplacian operator (default F)

! Direction of action :
! *ln traldf level* iso-level (default F)
! *ln traldf hor* horizontal (geopotential) (default F)^**
! *ln traldf iso* iso-neutral (default T)^*
! Coefficient
! aht0 horizontal eddy diffusivity for tracers (m2/s)
! ahtb0 background eddy diffusivity for isopycnal diffusion (m2/s)
! aeiv0 eddy induced velocity coefficient (m2/s)
! ^* require *key ldfslp* to compute the direction of the lateral diffusion
! ^** require *key ldfslp* in s-coordinate
&nam traldf
ln traldf lap = .true.
ln traldf bilap = .false.
ln traldf level = .false.
ln traldf hor = .false.
ln traldf iso = .true.
aht0 = 125.
ahtb0 = 0.
aeiv0 = 1600.
/
!——————————————————————————————
! nam dynldf lateral diffusion on momentum
!——————————————————————————————
! Type of the operator :
! *ln dynldf lap* laplacian operator (default T)
! *ln dynldf bilap* bilaplacian operator (default F)
! Direction of action :
! *ln dynldf level* iso-level (default F)
! *ln dynldf hor* horizontal (geopotential) (default F)^**
! *ln dynldf iso* iso-neutral (default T)^*
! Coefficient
! ahm0 horizontal eddy viscosity for the dynamics (m2/s)
! ahmb0 background eddy viscosity for isopycnal diffusion (m2/s)
&nam dynldf
ln dynldf lap = .false.
ln dynldf bilap = .true.
ln dynldf level = .false.
ln dynldf hor = .true.
ln dynldf iso = .false.
ahm0 = -1.e+10
ahmb0 = 0.
/
!——————————————————————————————
! namflg algorithm flags (algorithm not control by CPP keys)
!——————————————————————————————
! *ln dynhpg imp* hydrostatic pressure gradient: semi-implicit time scheme (T)
! centered time scheme (F)
! nn dynhpg rst add dynhpg implicit variables in restart ot not (1/0)
&namflg
ln dynhpg imp = .true.
nn dynhpg rst = 0
/
!——————————————————————————————
! nam dynhpg Hydrostatic pressure gradient option
!——————————————————————————————
! type of pressure gradient scheme (choose one only!)

! *ln hpg zco* z-coordinate - full steps (default T)
! *ln hpg zps* z-coordinate - partial steps (interpolation)
! *ln hpg sco* s-coordinate (standard jacobian formulation)
! *ln hpg hel* s-coordinate (helsinki modification)
! *ln hpg wdj* s-coordinate (weighted density jacobian)
! *ln hpg djc* s-coordinate (Density Jacobian with Cubic polynomial)
! *ln hpg rot* s-coordinate (ROTated axes scheme)
! parameters
! gamm weighting coefficient (wdj scheme)
&nam dynhpg
ln hpg zco = .false.
ln hpg zps = .true.
ln hpg sco = .false.
ln hpg hel = .false.
ln hpg wdj = .false.
ln hpg djc = .false.
ln hpg rot = .false.
gamm = 0.e0
/
!————————————————————————
! nam dynvor option of physics/algorithm (not control by CPP keys)
!————————————————————————
! *ln dynvor ens* vorticity trends: enstrophy conserving scheme (default T)
! *ln dynvor ene* " " : energy conserving scheme (default F)
! *ln dynvor mix* " " : mixed scheme (default F)
! *ln dynvor een* " " : energy & enstrophy scheme (default F)
&nam dynvor
ln dynvor ene = .false.
ln dynvor ens = .false.
ln dynvor mix = .false.
ln dynvor een = .true.
/
!————————————————————————
! namtau surface wind stress
!————————————————————————
! ntau000 gently increase the stress over the first ntau rst time-steps
! tau0x uniform value used as default surface heat flux
! tau0y uniform value used as default solar radiation flux
&namtau
ntau000 = 0
tau0x = 0.e0
tau0y = 0.e0
/
!————————————————————————
! namflx surface fluxes
!————————————————————————
! q0 uniform value used as default surface heat flux
! qsr0 uniform value used as default solar radiation flux
! emp0 uniform value used as default surface freswater budget (E-P)
! dqdt0 feedback coefficient for SST damping (W/m2/K)
! deds0 feedback coefficient for SSS damping (mm/day)
&namflx
q0 = 0.e0
qsr0 = 0.e0
emp0 = 0.e0
dqdt0 = -40.

deds0 = 0.
/
!————————————————————————————————
! namalb albedo parameters
!————————————————————————————————
! cgren correction of the snow or ice albedo to take into account
! albice albedo of melting ice in the arctic and antarctic
! alphd coefficients for linear interpolation used to compute albedo
! between two extremes values (Pyane, 1972)
! alphc " "
! alphdi " "
&namalb
cgren = 0.06
albice = 0.5
alphd = 0.80
alphc = 0.65
alphdi = 0.72
/
!————————————————————————————————
! namdom space and time domain (bathymetry, mesh, timestep)
!————————————————————————————————
! ntopo = 0/1 ,compute/read the bathymetry file
! (mbathy, nb of T-ocean levels)
! e3zps min the thickness of the partial step is set larger than the
! e3zps rat the minimum of e3zps min and e3zps rat * e3t
! (N.B. 0<e3zps rat<1)
! ngrid = 0/1, compute/read the horizontal mesh
! (coordinates, scale factors)
! nmsh =1 create a mesh file (coordinates, scale factors, masks)
! nacc the acceleration of convergence method
! = 0, no acceleration, rdt = rdttra
! = 1, acceleration used, rdt < rdttra(k)
! atfp asselin time filter parameter
! rdt time step for the dynamics (and tracer if nacc=0)
! rdtmin minimum time step on tracers
! rdtmax maximum time step on tracers
! rdth depth variation of tracer time step
! rdtbt barotropic time step (for the time splitting algorithm)
! nfice frequency of ice model call
! nfbulk frequency of bulk formulea call (not used if ice used)
! nclosea = 0 no closed sea
! = 1 closed sea (Black Sea, Caspian Sea, Great US Lakes...)
&namdom
ntopo = 1
e3zps min = 5.
e3zps rat = 0.1
ngrid = 1
nmsh = 0
nacc = 0
atfp = 0.1
rdt = 1200.
rdtmin = 1200.
rdtmax = 1200.
rdth = 1200.
rdtbt = 1200.
nfice = 5

nfbulk = 5
nclosea = 0
/
!———————————————————————————————
! namfwb freshwater budget correction
!———————————————————————————————
! *ln fwb* logical flag for freshwater budget correction (0 annual mean)
&namfwb
ln fwb = .true.
/
!———————————————————————————————
! namcro cross land advection
!———————————————————————————————
! n cla advection between 2 ocean pts separates by land
&namcla
n cla = 0
/
!———————————————————————————————
! namzdf vertical physics
!———————————————————————————————
! *ln zdfevd* enhanced vertical diffusion (default T)
! *ln zdfnpc* Non-Penetrative Convection (default T)
! avm0 vertical eddy viscosity for the dynamic (m2/s)
! avt0 vertical eddy diffusivity for tracers (m2/s)
! avevd vertical coefficient for enhanced diffusion scheme (m2/s)
! n evdm = 0 apply enhanced mixing on tracer only
! = 1 apply enhanced mixing on both tracer and momentum
! *ln zdfexp* vertical physics: (=T) time splitting (T) (Default=F)
! (=F) euler backward (F)
! n zdfexp number of sub-timestep for time splitting scheme
&namzdf
ln zdfevd = .true.
ln zdfnpc = .false.
avm0 = 1.e-4
avt0 = 1.e-5
avevd = 50.
n evdm = 1
ln zdfexp = .false.
n zdfexp = 3
/
!———————————————————————————————
! namnpc vnon penetrative convection
!———————————————————————————————
! nnpc1 non penetrative convective scheme frequency
! nnpc2 non penetrative convective scheme print frequency
&namnpc
nnpc1 = 1
nnpc2 = 365
/
!———————————————————————————————
! nambbl bottom boundary layer scheme
!———————————————————————————————
! atrbbl lateral tracer coeff. for bottom boundary layer scheme(m2/s)
&nambbl
atrbbl = 0.
/

!——————————————————————————————————
! namric richardson number dependent vertical diffusion
! (#ifdef "*key zdfrichardson*")
!——————————————————————————————————
! avmri maximum value of the vertical viscosity
! alp coefficient of the parameterization
! nric coefficient of the parameterization
&namwri
avmri = 100.e-4
alp = 5.
nric = 2
/
!——————————————————————————————————
! namtke turbulent eddy kinetic dependent vertical diffusion
! (#ifdef "*key zdftke*")
!——————————————————————————————————
! *ln rstke* flag to restart with tke from a run without tke (default F)
! ediff coef. to compute vertical eddy coef. (avt=ediff*mxl*sqrt(e))
! ediss coef. of the Kolmogoroff dissipation
! ebb coef. of the surface input of tke
! efave coef. to applied to the tke diffusion (avtke=efave*avm)
! emin minimum value of tke (m^2/s^2)
! emin0 surface minimum value of tke (m^2/s^2)
! nitke number of restart iterative loops
! ri c critic richardson number
! nmxl flag on mixing length used
! = 0 bounded by the distance to surface and bottom
! = 1 bounded by the local vertical scale factor
! = 2 first vertical derivative of mixing length bounded by 1
! npdl flag on prandtl number
! = 0 no vertical prandtl number (avt=avm)
! = 1 prandtl number function of richarson number (avt=pdl*avm)
! = 2 same as = 1 but a shapiro filter is applied on pdl
! nave = horizontal averaged (=1) or not (=0) of avt (default =1)
! navb = 0 cst background avt0, avm0 / =1 profile used on avtb
&namtke
ln rstke = .false.
ediff = 0.1
ediss = 0.7
ebb = 3.75
efave = 1.
emin = 1.e-6
emin0 = 1.e-4
nitke = 50
nmxl = 2
npdl = 1
navb = 0
/
!——————————————————————————————————
! namkpp K-Profile Parameterization dependent vertical diffusion
! (#ifdef "*key zdfkpp*")
!——————————————————————————————————
! *ln kpprimix* shear instability mixing (default T)
! difmiw constant internal wave viscosity (m2/s)
! difsiw constant internal wave diffusivity (m2/s)
! Riinfty local Richardson Number limit for shear instability

! difri maximum shear mixing at Rig = 0 (m2/s)
! bvsqcon Brunt-Vaisala squared (1/s**2) for maximum convection
! difcon maximum mixing in interior convection (m2/s)
! nave = 0/1 flag for horizontal average on avt, avmu, avmv
! navb = 0/1 flag for constant or profile background avt
&namkpp
ln kpprimix = .true.
difmiw = 1.e-04
difsiw = 0.1e-04
Riinfty = 0.8
difri = 0.0050
bvsqcon = -0.01e-07
difcon = 1.
navb = 0
nave = 1
/
!——————————————————————————
! namddm double diffusive mixing parameterization
!——————————————————————————
! avts maximum avs for dd mixing
! hsbfr heat/salt buoyancy flux ratio
&namddm
avts = 1.e-4
hsbfr = 1.6
/
!——————————————————————————
! namlbc lateral momentum boundary condition
!——————————————————————————
! shlat lateral boundary condition on velocity
! shlat = 0 , free slip
! 0 < shlat < 2 , partial slip
! shlat = 2 , no slip
! 2 < shlat , strong slip
&namlbc
shlat = 2
/
!——————————————————————————
! nambfr bottom friction
!——————————————————————————
! nbotfr type of bottom friction
! nbotfr = 0 , no slip
! nbotfr = 1 , linear friction
! nbotfr = 2 , nonlinear friction
! nbotfr = 3 , free slip
! bfri1 bottom drag coefficient (linear case)
! bfri2 bottom drag coefficient (non linear case)
! bfeb2 bottom turbulent kinetic energy (m^2/s^2)
&nambfr
nbotfr = 2
bfri1 = 4.e-4
bfri2 = 1.225e-3
bfeb2 = 2.5e-3
/
!——————————————————————————
! nambbc bottom temperature boundary condition
!——————————————————————————

! ngeo flux = 0 no geothermal heat flux
! = 1 constant geothermal heat flux
! = 2 variable geothermal heat flux (read in *geothermal heating.nc*)
! (C A U T I O N : flux in mW/m2 in the NetCDF file)
! ngeo flux const Constant value of geothermal heat flux (W/m2)
&nambbc
ngeo flux = 0
ngeo flux const = 88.0e-3
/
!————————————————————————————
! namqsr penetrative solar radiation
!————————————————————————————
! *ln traqsr* : penetrative solar radiation (T) or not (F) (Default=T)
! rabs fraction of qsr associated with xsi1
! xsi1 first depth of extinction
! xsi2 second depth of extinction
! *ln qsr sms* : Biological fluxes for light(Y/N)
&namqsr
ln traqsr = .true.
rabs = 0.58
xsi1 = 0.35
xsi2 = 23.0
! *ln qsr sms* = .false.
/
!————————————————————————————
! namtdp tracer newtonian damping ('*key tradmp*')
!————————————————————————————
! ndmp type of damping in temperature and salinity
! (='latitude', damping poleward of 'ndmp' degrees and function
! of the distance-to-coast. Red and Med Seas as ndmp=-1)
! (=-1 damping only in Med and Red Seas)
! ndmpf =1 create a damping.coeff NetCDF file (the 3D damping array)
! nmldmp type of damping in the mixed layer
! (=0 damping throughout the water column)
! (=1 no damping in the mixed layer defined by avt >5cm2/s)
! (=2 no damping in the mixed layer defined rho<rho(surf)+.01)
! sdmp surface time scale for internal damping (days)
! bdmp bottom time scale for internal damping (days)
! hdmp depth of transition between sdmp and bdmp (meters)
&namtdp
ndmp = -1
ndmpf = 2
nmldmp = 0
sdmp = 90.
bdmp = 360.
hdmp = 800.
/
!————————————————————————————
! nameos ocean physical parameters
!————————————————————————————
! neos type of equation of state and Brunt-Vaisala frequency
! = 0, UNESCO (formulation of Jackett and McDougall (1994)
! and of McDougall (1987))
! = 1, linear: rho(T) = rau0 * (1.028 - ralpha * T)
! = 2, linear: rho(T,S) = rau0 * (rbeta * S - ralpha * T)
! with rau0=1020 set in parcst routine

! ralpha thermal expension coefficient (linear equation of state)
! rbeta saline expension coefficient (linear equation of state)
&nameos
neos = 0
ralpha = 2.e-4
rbeta = 0.001
/
!——————————————————————————
! namsol elliptic solver / island / free surface
!——————————————————————————
! nsolv elliptic solver (=1 preconditioned conjugate gradient: pcg)
! (=2 successive-over-relaxation: sor)
! (=3 FETI: fet, all require "*key feti*" defined)
! (=4 sor with extra outer halo)
! nsol arp absolute/relative (0/1) precision convergence test
! nmin minimum of iterations for the SOR solver
! nmax maximum of iterations for the solver
! nmod frequency of test for the SOR solver
! eps absolute precision of the solver
! resmax absolute precision for the SOR solver
! sor optimal coefficient for sor solver
! epsisl absolute precision on stream function solver
! nmisl maximum pcg iterations for island
! rnu strength of the additional force used in free surface b.c.
&namsol
nsolv = 2
nsol arp = 0
nmin = 300
nmax = 15000
nmod = 10
eps = 1.E-6
resmax = 1.E-10
sor = 1.76
epsisl = 1.e-12
nmisl = 5000
rnu = 1.
/
!===
! Diagnostics namelists
! namtrd dynamics and/or tracer trends
! namgap level mean model-data gap
! namznl zonal mean heat & freshwater fluxes computation
! namspr surface pressure in rigid-lid
!===
!——————————————————————————
! namtrd diagnostics on dynamics and/or tracer trends
! ('*key diatrdyn*' and/or '*key diatrtra*')
! or mixed-layer trends ('*key diatrdmld*')
!——————————————————————————
! ntrd time step frequency dynamics and tracers trends
! nctls control surface type in mixed-layer trends (0,1 or n<jpk)
! *ln trdmld* restart restart for ML diagnostics
! ucf unit conversion factor (=1 -> /seconds | =86400. -> /day)
! *ln trdmld* instant flag to diagnose trends of instantantaneous or mean ML T/S
&namtrd
ntrd = 365

nctls = 0
ln trdmld restart = .false.
ucf = 1.
ln trdmld instant = .false.
/
!——————————————————————————————
! namgap level mean model-data gap ('*key diagap*')
!——————————————————————————————
! ngap time-step frequency of model-data gap computation
! nprg time-step frequency of gap print in model output
&namgap
ngap = 15
nprg = 10
/
!——————————————————————————————
! namznl zonal mean heat & freshwater fluxes computation
! (#ifdef "*key diaznl*")
!——————————————————————————————
! nfznl time-step frequency of zonal mean fluxes computation
&namznl
nfznl = 15
/
!——————————————————————————————
! namspr surface pressure diagnostic
!——————————————————————————————
! nmaxp maximum of iterations for the solver
! epsp absolute precision of the solver
! niterp number of iteration done by the solver
&namspr
nmaxp = 1000
epsp = 1.e-3
niterp = 400
/
!——————————————————————————————
! namcpl coupled ocean/atmosphere model
!(#ifdef "*key coupled*" NOT "*key oasis3*")
!——————————————————————————————
! nexco coupling frequency in time steps
! cchan coupling technique 'PIPE' or 'CLIM'
&namcpl
nexco = 24
cchan = 'PIPE'
nmodcpl = 2
cplmodnam = 'opa.xx'
cploasis = 'Oasis'
nfldo2c = 2
nflxc2o = 6
ntauc2o = 4
cpl writ(1) = 'SOSSTSST'
cpl f writ(1) = 'ocesst'
cpl writ(2) = 'SOICECOV'
cpl f writ(2) = 'oceice'
cpl readflx(1) = 'SONSFLDO'
cpl f readflx(1) = 'oceflx'
cpl readflx(2) = 'SOSHFLDO'
cpl f readflx(2) = 'oceflx'

cpl readflx(3) = 'SOTOPRSU'
cpl f readflx(3) = 'oceflx'
cpl readflx(4) = 'SOTFSHSU'
cpl f readflx(4) = 'oceflx'
cpl readflx(5) = 'SORUNCOA'
cpl f readflx(5) = 'oceflx'
cpl readflx(6) = 'SORIVFLU'
cpl f readflx(6) = 'oceflx'
cpl readtau(1) = 'SOZOTAUX'
cpl f readtau(1) = 'ocetau'
cpl readtau(2) = 'SOZOTAU2'
cpl f readtau(2) = 'ocetau'
cpl readtau(3) = 'SOMETAUY'
cpl f readtau(3) = 'ocetau'
cpl readtau(4) = 'SOMETAU2'
cpl f readtau(4) = 'ocetau'
/
!————————————————————————————
! namobc open boundaries parameters (#ifdef *key obc*)
!————————————————————————————
! nobc dta = 0 the obc data are equal to the initial state
! = 1 the obc data are read in 'obc .dta' files
! rdpeob time relaxation (days) for the east open boundary
! rdpwob time relaxation (days) for the west open boundary
! rdpnob time relaxation (days) for the north open boundary
! rdpsob time relaxation (days) for the south open boundary
! zbsic1 barotropic stream function on isolated coastline 1
! zbsic2 barotropic stream function on isolated coastline 2
! zbsic3 barotropic stream function on isolated coastline 3
! *ln obc clim* climatological obc data files (default T)
! *ln vol cst* total volume conserved
&namobc
nobc dta = 0
rdpein = 1.
rdpwin = 1.
rdpnin = 30.
rdpsin = 1.
rdpeob = 1500.
rdpwob = 15.
rdpnob = 150.
rdpsob = 15.
zbsic1 = 140.e+6
zbsic2 = 1.e+6
zbsic3 = 0.
ln obc clim = .true.
ln vol cst = .false.
/
!————————————————————————————
! namflo float parameters (#ifdef *key float*)
!————————————————————————————
! *ln rstflo* boolean term for float restart (true or false)
! nwritefl frequency of float output file
! nstockfl frequency of float restart file
! *ln argo* Argo type floats (stay at the surface each 10 days)
! *ln flork4* = T trajectories computed with a 4th order Runge-Kutta
! = F (default) computed with Blanke' scheme

&namflo
ln rstflo = .false.
nwritefl = 75
nstockfl = 5475
ln argo = .false.
ln flork4 = .false.
/
!————————————————————————
! nam traadv bilap flag advection bilaplacian scheme for tracer
!————————————————————————
! *ln traadv bilap* bilaplacian scheme (default F)
&nam traadv bi
ln traadv bilap = .false.
/
!————————————————————————
! namdct transport (#ifdef *key transport*)
!————————————————————————
! nwdct frequency of transport output file
&namdct
nwdct = 720
/
!————————————————————————
! namoor mooring stuff (#ifdef *key mooring*)
!————————————————————————
! nwmoor number of time step between mooring dumps
&namoor
nwmoor = 720
/
!————————————————————————
! namxbt section stuff (#ifdef *key xbt*)
!————————————————————————
! nwsect number of time step between section dumps
&namxbt
nwsect = 720
/
!————————————————————————
! namptr Poleward transport of heat and salt
!————————————————————————
! *ln diaptr* Switch for ptr diagnostic (T) or not (F)
! *ln subbas* Atla/Paci/Ind basins computation
! nf ptr Frequency of computation
&namptr
ln diaptr = .false.
ln subbas = .false.
nf ptr = 15
/
!————————————————————————
! namerp new method of sss relaxation ('*key erp array*')
!————————————————————————
! erp01 to erp12 : value of erp prescribed for month 1 to 12
&namerp
erp01 = 2.983e-6
erp02 = 2.173e-6
erp03 = 4.298e-6
erp04 = 3.546e-6
erp05 = -1.803e-6

erp06 = -5.076e-6
erp07 = -8.116e-6
erp08 = -4.957e-6
erp09 = 3.028e-6
erp10 = 9.123e-6
erp11 = 12.010e-6
erp12 = 10.500e-6
/

Parameter	**Mean and standard deviation 1961-2000**
Inflow at Gibraltar	$0.87 \pm 0.03\ Sv$
Outflow at Gibraltar	$-0.82 \pm 0.03\ Sv$
Net water flux at Gibraltar	$0.05 \pm 0.01\ Sv$, i.e. $1.78 \pm 0.18\ mm/d$
Water flux through the surface	$1.78 \pm 0.18\ mm/d$
Heat flux through the surface	$-2.9 \pm 3.8\ W/m^2$, i.e. $-2.2.10^{20}\ J/yr$
Heat flux at Gibraltar	$+5.2 \pm 0.5\ W/m^2$, i.e. $+4.0.10^{20}\ J/yr$
Heat content of the Mediterranean	$+0.002\ C/yr$, i.e. $+0.4.10^{20}\ J/yr$
Salt flux at Gibraltar	$3.8 \pm 6.6.10^{15} g/yr$, i.e. $+0.0009 psu/yr$
Salt content of the Mediterranean	$+3.5.10^{15} g/yr$, i.e. $+0.0009 psu/yr$

Table 3: *Budgets of the 1961-2000 simulation*

11 Conclusion

The NEMOMED8 regional oceanic model of the Mediterranean Sea has been presented. It is built as a new configuration of the NEMO-v2 oceanic model, controlled by keys of compilation, but the modified codes of NEMO-v2 kept at the CNRM are needed for its construction.

The model can be used in forced or coupled mode, and a new type of communication with the global ORCA2 version of NEMO-v2 is also presented, via exchange of files containing informations on the Gibraltar strait.

The model is still moving, with new improvements concerning for example the use of river runoffs coming from coupling fields (with the aim of using a model like TRIP [Oki and Sud 1998] for the routing between the atmosphere and the ocean), but also the possibility of introducing new diagnosis when needed. This documentation is a first milestone in its evolution.

Many tests are also to be done concerning the physics of the model, among others at the Gibraltar strait, the Dardanelles strait, but also concerning the choices made for the advection and diffusion inside the water mass.

A forty year experiment has been presented, the model receiving the atmospheric fluxes coming from ARPEGE-Climate in its stretched version with large scales driven by ERA40: the comparison of the chronology of the state of the sea with the Rixen's climatology is in itself a confirmation of the quality of the atmospheric forcings and of the capacity of the NEMOMED8 model to represent the Mediterranean basin.

Acknowledgments

The specific codes for the Mediterranean Sea come from the OPA9 Mediterranean version of A. Bozec. K. Beranger gave me some advice and some parts of her MED16 model. For the coupled version E. Maisonnave gave me his modifications of NEMO for the OASIS3 coupler.

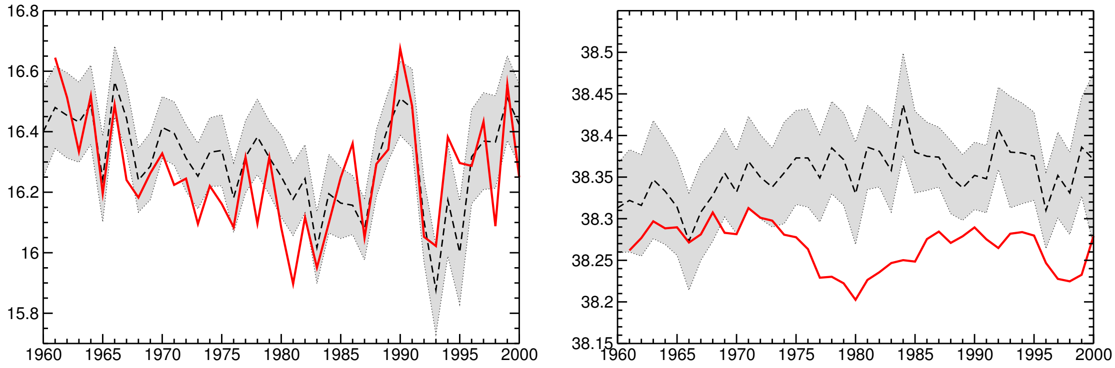

Figure 4: Comparison of T (left) and S (right) of the 0-150m layer with the Rixen's climatology in grey.

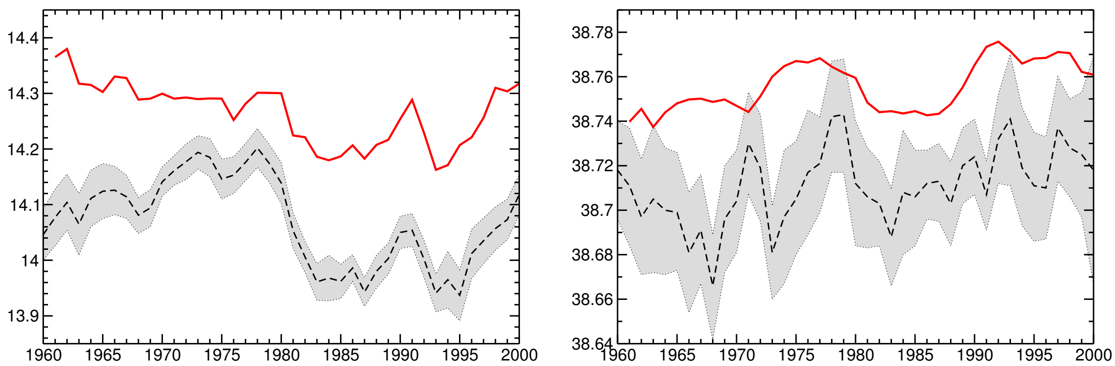

Figure 5: Comparison of T (left) and S (right) of the 150m-600m layer with the Rixen's climatology in grey.

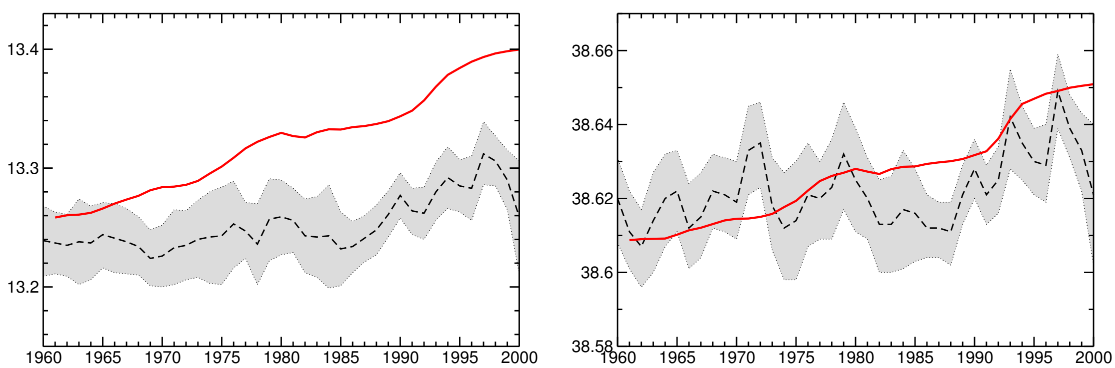

Figure 6: Comparison of T (left) and S (right) of the 600m-bottom layer with the Rixen's climatology in grey.

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