Balancing the Modular Ocean Model for Mediterranean Ecosystem

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ABSTRACT – *In questa memoria comunichiamo l'accoppiamento del modello di circolazione generale MOM (Pakanowsky et al., 1993) con l'evoluzione spazio-temporale delle componenti organiche presenti nella zona eufotica e con la rimineralizzazione organica nella zona afotica del Mediterraneo, denominata ECHYM nel seguito (Crispi et al., 2002).*

Le simulazioni hanno comportato un tempo di esecuzione pari a 200000 UAC complessive sulla SGI Origin3800 del CINECA.

In this note we communicate the integration of Modular Ocean Model (Pakanowsky et al., 1993) with spatial and temporal evolution of organic compounds present in the euphotic zone and inorganic remineralization in the aphotic zone of the Mediterranean Sea, as acronym ECHYM - ECoHYdrodynamical model of the Mediterranean (Crispi et al., 2002).

The simulations were completed on the SGI Origin3800 in the classical configuration with 128 MIPS R14000 with a CPU at 500 MHz at 128 Gbyte di RAM spanning a total execution time of 200000 UAC.

1. ECHYM experiments

The aim of these experiments is shown in Fig. 1, from an initial condition "RUN WITH RIVERS AND SEAS" we run through "UNPERTURBED RUN", via the black arrow, and after the "BALANCED RUN" is obtained, we will go back to "RUN WITH RIVERS AND SEAS", through the grey arrow.

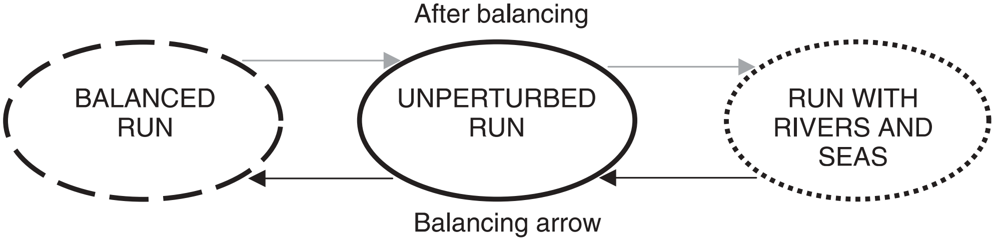

FIGURE 1. – *Experiments plan.*

It follows the tracer equation employed during MOM calculations

$$\frac{\partial Tracer}{\partial t} + \vec{V} \bullet \vec{\nabla} Tracer + [- K_H \vec{\nabla}_H^4 (Tracer) + K_V \frac{\partial^2 Tracer}{\partial z^2}] +$$
$$+ W_{Sinking} = Source/Sink, \quad with\, W_{Sinking} \neq 0$$

Where K_H and K_V are the horizontal biharmonic and vertical harmonic constant turbulent diffusion coefficients, $W_{sinking}$ takes account for sinking velocity (null in this case) of the tracer while Source/Sink represents all the biological and chemical sources or sinks for variable Tracer.

The previous test, numbered as 8, has a time duration of 2 months with no relaxation for Gibraltar. Nitrogen and Phosphorus balances are obtained with this run and the next control run is test 9 with an execution time of 24 months.

In order to compare each Mediterranean region, we consider the following definitions:

MEDGIB → Mediterranean Sea included Gibraltar
MED → Mediterranean Sea without Gibraltar
EASTMED → East Mediterranean
WESTMED → West Mediterranean

TABLE 1. – Nitrogen and Phosphorus total content, for two year model simulation, in the area MEDGIB.

Month	Total Nitrogen [μMol]	Total Phosphorus [μMol]
Feb.	0.2098140E+20	0.9905935E+18
Mar.	0.2098140E+20	0.9905935E+18
Apr.	0.2098140E+20	0.9905935E+18
May	0.2098140E+20	0.9905935E+18
Jun.	0.2098140E+20	0.9905935E+18
Jul.	0.2098140E+20	0.9905935E+18
Aug.	0.2098140E+20	0.9905935E+18
Sep.	0.2098140E+20	0.9905935E+18
Oct.	0.2098140E+20	0.9905935E+18
Nov.	0.2098140E+20	0.9905935E+18
Dec.	0.2098140E+20	0.9905935E+18
Jan.	0.2098140E+20	0.9905935E+18
Feb.	0.2098140E+20	0.9905935E+18
Mar.	0.2098140E+20	0.9905935E+18
Apr.	0.2098140E+20	0.9905935E+18
May	0.2098140E+20	0.9905935E+18
Jun.	0.2098141E+20	0.9905935E+18
Jul.	0.2098141E+20	0.9905935E+18
Aug.	0.2098140E+20	0.9905936E+18
Sep.	0.2098140E+20	0.9905935E+18
Oct.	0.2098140E+20	0.9905936E+18
Nov.	0.2098141E+20	0.9905935E+18
Dec.	0.2098142E+20	0.9905935E+18
Jan.	0.2098142E+20	0.9905935E+18

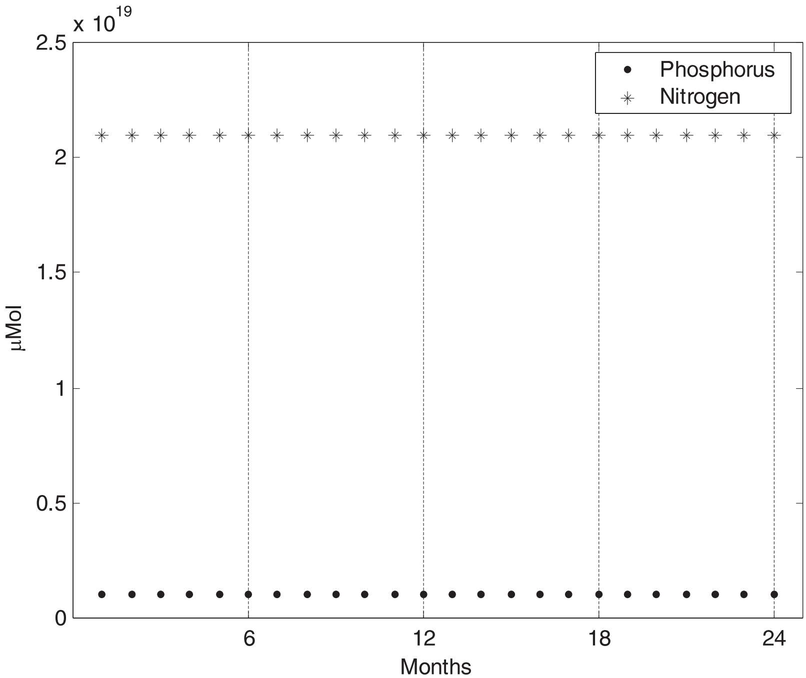

FIGURE 2. – *Total Nitrogen and Phosphorus, in the area MEDGIB, during two years of model simulation ("prova9.2y.bio"). The maximal error on the total estimation is about 70 tons and 1.6 tons respectively for Nitrogen and Phosphorus.*

Nitrogen standard deviation	Phosphorus standard deviation
8.6811E+12 [μMol]	5.8359E+10 [μMol]

Since the error relative to the first year doesn't exceed 5.0E+12 μMol N and 5.0E+10 μMol P, by converting from μMol to tons, using the following

1ton = 1μMolE-6*Molecular weight*1E-6
we have a maximal error on the total estimation of about
70 tons for Nitrogen
1.6 tons for Phosphorus
during the first year of model simulation.

Looking at table 1 it is clear that Nitrogen is preserved with an imprecision on the eighth digit after comma (first year), or with an error of 0.07 10^3 tons while Phosphorus with an error of about 0.0016 10^3 tons.

In Fig. 3 trends relative to Ultraplankton, Netplankton and Zooplankton during 24 months of simulation are shown. At the beginning there is a considerable contribution of Netplankton while in the second year the biomasses are more equilibrated.

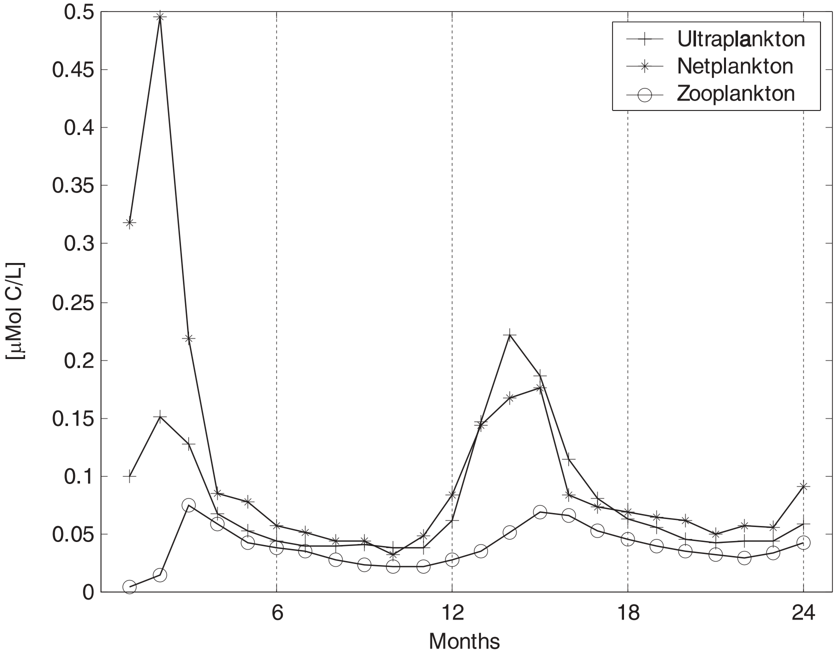

FIGURE 3. – *Ultraplankton, Netplankton and Zooplankton, area MEDGIB.*

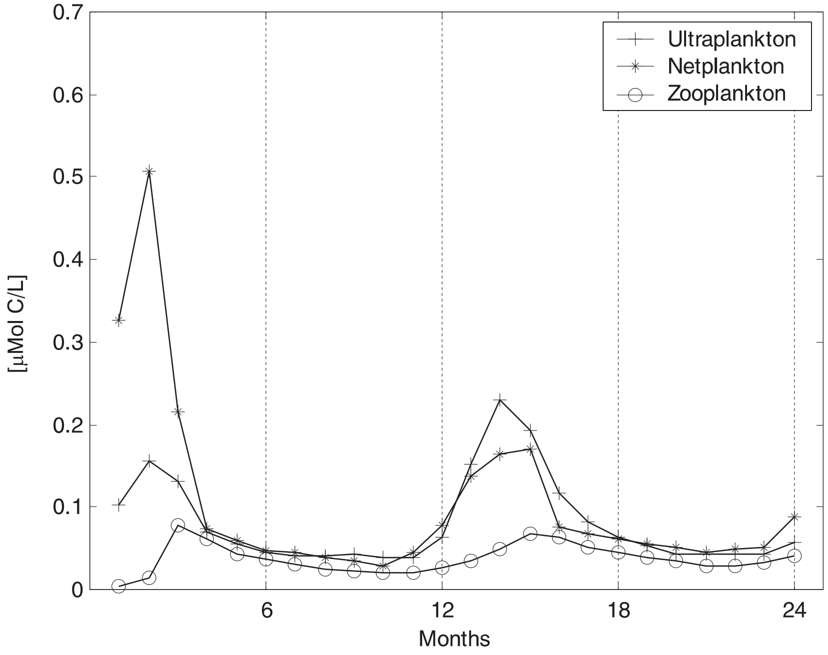

FIGURE 4. – *Ultraplankton, Netplankton and Zooplankton, area MED.*

TABLE 2. – Tot_N (January first year) minus tot_N (January second year) and difference between tot_N (January second year) and tot_N (January third year), same for Phosphorus.

Region	Nitrogen [10^3 ton]	Phosphorus [10^3 ton]
MED (0÷12)	−194.04	39.19
MED (12÷24)	156.38	108.87

It follows the mean gain/lost relative to Nitrogen and Phosphorus during the second year.

TABLE 3. – Difference between tot_N (24° month) and tot_N (12° month), same for Phosphorus.

Region	Nitrogen [10^3 ton]	Phosphorus [10^3 ton]
WESTMED	993.006	95.321
EASTMED	−837.060	13.547

In the area ESTMED a Phosphorus loss appears during the first year, but subsequently it changes sign showing a gain and seems stabilized after 20 months. In WESTMED Phosphorus content increases (probably due to Gibraltar).

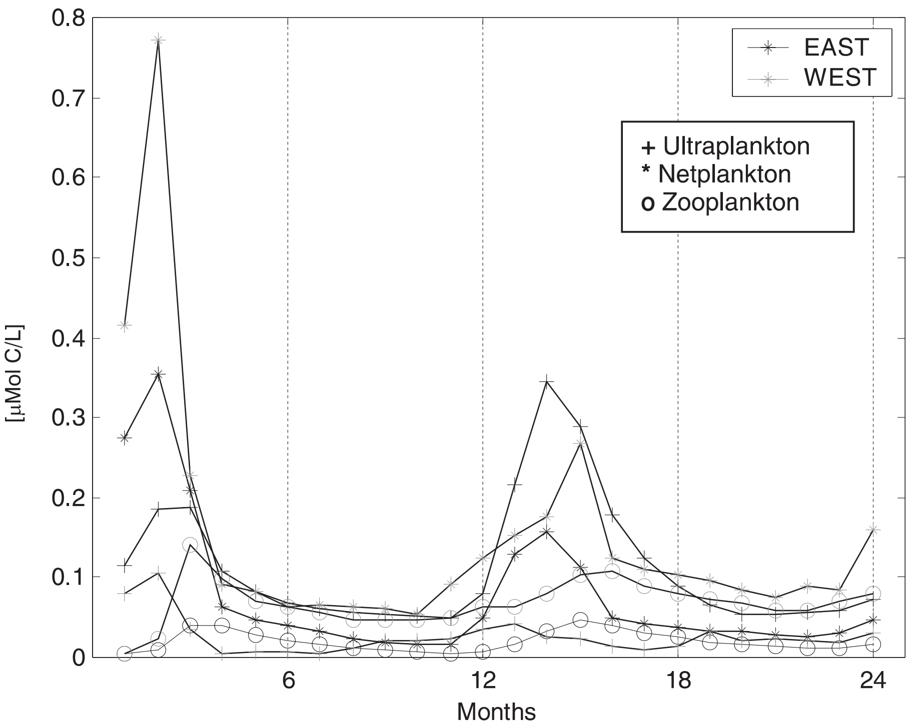

FIGURE 5. – *Biomass in the West/East Mediterranean.*

The eastern biomass when averaged in the 24 months is shown in table 4.

TABLE 4. – Monthly averaged biomass, Eastern Mediterranean.

Month	Ultraplankton gC/(m^2)	Netplankton gC/(m^2)	Zooplankton gC/(m^2)
Feb.	1.6434895	5.0024681	0.0256463
Mar.	2.9231145	5.6567879	0.1498513
Apr.	2.8622448	3.0857694	0.6917216
May	1.7409587	1.0004187	0.6759939
Jun.	1.4414772	0.8517597	0.4856585
Jul.	1.2515442	0.7360420	0.3878610
Aug.	1.1508027	0.6072033	0.2946976
Sep.	1.0770288	0.4716101	0.2184986
Oct.	1.0515761	0.3746466	0.1604151
Nov.	0.9787871	0.3025509	0.1172260
Dec.	0.9236069	0.3316934	0.0886987
Jan.	1.4485606	0.9240119	0.1188808
Feb.	3.0854023	1.9755197	0.2899256
Mar.	4.1385636	2.1356370	0.4748752
Apr.	3.5109451	1.7767450	0.7151654
May	2.3750679	0.8205654	0.6533167
Jun.	1.8129882	0.7466193	0.5383521
Jul.	1.4460139	0.6831027	0.4494872
Aug.	1.1139182	0.6300111	0.3592692
Sep.	0.9895326	0.6284959	0.2952704
Oct.	1.0059994	0.5310822	0.2479027
Nov.	1.0813966	0.5125074	0.2213249
Dec.	1.1357985	0.5833910	0.2242607
Jan.	1.3616195	0.8797489	0.3227164

Ultraplankton biomass (second year only)	1.93 gC/(m^2)
Netplankton biomass (second year only)	1.00 gC/(m^2)
Zooplankton biomass (second year only)	0.38 gC/(m^2)

The western biomass as averaged in the 24 months shown in table 5.

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[5] R.C. Pakanowsky, K. Dixon, and A. Rosati, 1993. READ_ME text file of GFDL MOM1.1, Geophysical Fluid Dynamics Laboratory, Princeton, N.J.

[6] V. Roussenov, E. Stanev, V. Artale and N. Pinardi, 1995. A seasonal model of the Mediterranean Sea general circulation. J. Geoph. Res., 100(C7), 13515-13538.

TABLE 5. – Monthly averaged biomass, Western Mediterranean.

Month	Ultraplankton gC/(m^2)	Netplankton gC/(m^2)	Zooplankton gC/(m^2)
Feb.	1.0711241	5.0024681	0.0256463
Mar.	1.8318365	5.6567879	0.1498513
Apr.	0.5691771	3.0857694	0.6917216
May	0.0497659	1.0004187	0.6759939
Jun.	0.1143146	0.8517597	0.4856585
Jul.	0.1273603	0.7360420	0.3878610
Aug.	0.1184142	0.6072033	0.2946976
Sep.	0.2556981	0.4716101	0.2184986
Oct.	0.4192099	0.3746466	0.1604151
Nov.	0.4278503	0.3025509	0.1172260
Dec.	0.4702283	0.3316934	0.0886987
Jan.	0.7389442	0.9240119	0.1188808
Feb.	0.8128291	1.9755197	0.2899256
Mar.	0.4502091	2.1356370	0.4748752
Apr.	0.4050030	1.7767450	0.7151654
May	0.2410320	0.8205654	0.6533167
Jun.	0.1698282	0.7466193	0.5383521
Jul.	0.2977850	0.6831027	0.4494872
Aug.	0.6509559	0.6300111	0.3592692
Sep.	0.4493245	0.6284959	0.2952704
Oct.	0.4991187	0.5310822	0.2479027
Nov.	0.4361859	0.5125074	0.2213249
Dec.	0.3622958	0.5833910	0.2242607
Jan.	0.6290253	0.8797489	0.3227164

Ultraplankton biomass (second year only) 0.46 gC/(m^2)
Netplankton biomass (second year only) 2.46 gC/(m^2)
Zooplankton biomass (second year only) 1.49 gC/(m^2)

In tables 6 and 7 are reported the values at primary and secondary productions respectively in the Eastern and Western Mediterranean.

TABLE 6. – Primary and secondary production during the second year in the Eastern Mediterranean.

Month	Ultraplankton gC/(m^2 month)	Netplankton gC/(m^2 month)	Zooplankton gC/(m^2 month)
Jan.	3.1659894	3.0704210	0.2538925
Feb.	6.6713800	5.9683676	0.5448610
Mar.	8.6339607	6.3505454	0.8079214
Apr.	8.3209896	5.7508454	0.9866884
May	5.6794939	2.5516686	0.7393617
Jun.	4.1645274	2.5790098	0.5900722
Jul.	3.0997150	2.2531059	0.4980727
Aug.	2.2117615	1.9846188	0.3994765
Sep.	1.9538987	1.8581769	0.3398420
Oct.	1.9562845	1.4851898	0.2957408
Nov.	2.0212650	1.4683348	0.2834714
Dec.	2.1726675	1.8109897	0.3453693

Mean primary production relative to Ultraplankton (second year only) 50.051 gC/(m^2 year)

Mean primary production relative to Netplankton (second year only)	37.131 gC/(m^2 year)
Total primary production (second year only)	87.182 gC/(m^2 year)
Mean secondary production (second year only)	6.084 gC/(m^2 year)

TABLE 7. – Primary and secondary production during the second year in the Western Mediterranean.

Month	Ultraplankton gC/(m^2 month)	Netplankton gC/(m^2 month)	Zooplankton gC/(m^2 month)
Jan.	3.2857237	13.7487364	1.6760048
Feb.	3.1503098	15.2354956	1.6229345
Mar.	1.8626529	19.3145695	2.1217842
Apr.	1.9733160	31.1028748	2.6536422
May	1.4521712	16.7471733	2.4210031
Jun.	1.0047865	14.8349590	1.9000059
Jul.	1.8397293	13.2631683	1.8659023
Aug.	3.3579915	11.4892893	1.7774090
Sep.	2.1204810	10.0113039	1.6027799
Oct.	2.1900570	8.3777933	1.4094971
Nov.	1.8178124	9.7129745	1.6160784
Dec.	1.9270864	11.2150640	2.0297542

Mean primary production relative to Ultraplankton (second year only)	25.98 gC/(m^2 year)
Mean primary production relative to Netplankton (second year only)	175.05 gC/(m^2 year)
Total primary production (second year only)	201.03 gC/(m^2 year)
Mean secondary production (second year only)	22.69 gC/(m^2 year)

2. Conclusions

In this note it was shown that a MOM-like ecology of the Mediterranean Sea, forced as in Roussenov et al. (1995) and in Castellari et al. (1998), can be balanced.

Thus the numerical results are in good accord with the previous Nitrogen aggregated models (Crise et al., 1998; Crispi et al., 1998), but with the Phosphorus flux estimation.

An estimation of the errors has been carried out both for Phosphorus and Nitrogen total components.

The introduction of Nile and Rhone nutrients (Phosphate and Nitrate) contribution has also been validated by using a Matlab program which evaluates each geographical region volume (integrating cells volumes), for both rivers, considering a first level depth of 10 meters; tracer contents are obtained by multiplying these volumes with rivers flows and a water-land mask.

In addition, an accurate check has been conducted when using “jc” index, the memory slab window pointer, both for river inputs and Adriatic and Aegean marginal boxes. Moreover their identification in step-wise tracers subroutines has been homogeneously controlled.