Biomass data assimilation set-up and performances

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ABSTRACT – *Nell'ambito del progetto MFSTEP della Commissione Europea riguardante il Sistema di Previsione in Mediterraneo nella direzione della previsione delle variabili ambientali ed ecologiche, l'Istituto Nazionale di Oceanografia e di Geofisica Sperimentale-OGS di Trieste ha collaborato attivamente con il Supercomputing Group del CINECA di Bologna al fine di determinare un modello accoppiato idrodinamico ed ecologico in Mediterraneo basato sull'azoto inorganico e organico e sul plancton nelle stesse unità di azoto, ed inoltre ottimizzando le risorse di calcolo e nel gestire i dati di uscita.*

Nella prima fase di "set-up" sono state impiegate circa 100 ore di calcolo su SP4 nel 2004 per l'assimilazione di dati di fitoplancton nella simulazione con condizioni iniziali modificate, quindi differenti da quelle della simulazione di riferimento. Durante la seconda fase, in cui sono state utilizzate circa 500 ore di calcolo passando sulla nuova piattaforma IBM SP5, si è valutato l'effetto durante periodi di tempo decennali sul contenuto totale di azoto, dovuto ad immissione di materia organica ed inorganica in superficie, conseguendo un'incoraggiante situazione di equilibrio dell'ecosistema a più lungo termine, dopo oltre 30 anni di simulazione.

In the framework of the EC MFSTEP Project regarding the Mediterranean Forecasting System in the direction of forecasting of the environmental and ecological variables, the Istituto Nazionale di Oceanografia e di Geofisica Sperimentale-OGS in Trieste has actively cooperated with the CINECA Supercomputing Group in Bologna for determining a coupled hydrodynamical and ecological model in the Mediterranean Sea based upon inorganic and organic nitrogen, and on plankton in the same nitrogen units, moreover for optimising the computing resources and managing the outputs.

100 CPU hours have been used during the first set-up phase in the 2004 for assimilating phytoplankton data in the simulation with modified initial conditions, i. e. different from the reference simulation ones. During the second phase, the effects along decadal times upon total nitrogen content have been evaluated. The organic and inorganic matter inputs at surface induce really stable equilibrium situation of the ecosystem at longer times, after more than thirty years of dynamics, using about 500 hours of computing time on the new platform IBM SP5.

The ecological model

The ecosystem description concerning the general circulation with three-dimensional models has been set up according with the implementation at one eighth of degree during MFSPP[1].

3-D hydrodynamics equations with relevant boundary conditions are solved on the numerical B-grid with 31 vertical levels.

The description of the ecological processes is determined by NPZD model, Nitrate, N, Phytoplankton, P, Zooplankton, Z, and Detritus, D, as developed at OGS during EC Project MERMAIDS II[2].

The 3-D coupling of the biological tracer with hydrodynamics and its parameterization are on the same grid of the Mediterranean circulation model, one eighth degree [1].

The system of optimal interpolation is the SOFA - System for Ocean Forecasting and Interpolation 3.0 version, as released by LEGOS in Toulouse during Preliminary Phase of MFS at one eighth degree of resolution[3]. It has been used during MFSPP for assimilating various strategies of XBT, expendable bathythermograph, at VOS, volunteer observing ship tracks, airborne XBT and SST[4].

Resources and execution improvements

The original *hydrodynamics plus optimal interpolation system* has been tested at the 8 CPUs OGS SGI server. The operating system requires no change in the code, and minor changes in the applications libraries with the reinstallation of the COMPLIB library. The two days test starting from 1 February 200 conditions is successfully performed giving an elapsed time of 9 m and 24 s.

This *hydrodynamics plus optimal interpolation system* has been ported, customized and tested on the CINECA IBM-SP4-AIX 5.1 with 48 nodes, 512 POWER 4 1.3 Hz CPU's., 1088 GB RAM. To the aim of *integrating ecological processes* the biochemical modules and the compiler options are modified in MOM to introduce time-run evaluations and system supported functions. The required ESSL and LAPACK libraries are substituted by the optimized MASS library.

1 E. Demirov, and N. Pinardi, 2002. Simulation of the Mediterranean Sea circulation from 1979 to 1993: Part I. The interannual variability. J. Mar. Syst., 33-34, 23-50.

2 G. Crispi, A. Crise and C. Solidoro, 1998. Three-dimensional oligotrophic ecosystem models driven by physical forcing: the Mediterranean Sea case. Env. Model. Soft., 13, 483-490.

3 P. De Mey, and M. Benkiran, 2002. A Multivariate Reduced-order Optimal Interpolation Method and its Application to the Mediterranean Basin-scale Circulation. In: Ocean Forecasting: conceptual basis and applications, edited by N. Pinardi and J. Woods. Springer-Verlag, 281-306.

4 F. Raicich, and A. Rampazzo, 2003. Observing System Simulation Experiment for the assessment of temperature sampling strategies in the Mediterranean Sea. Ann. Geoph., 21, 151-165.

TABLE 1. – Different optimization options versus elapsed times, spanning time is one day simulation starting from 1st February 2000.

Test no.	optimization	qarch	qtune	qcache	qhot	Q	qipa	level	MASS	seconds
1	O0					No		0	No	>600
2	O2					No		0	No	262
3	O3					No		0	No	264
4	O2	pwr4	pwr4			No		0	No	255
5	O2	pwr4	pwr4	auto	novector	No		0	No	241
6	O2	pwr4	pwr4	auto	vector	No		0	No	239
7	O2	pwr4	pwr4	auto	novector	Yes	Yes	0	No	241
8	O2	pwr4	pwr4	auto	novector	Yes	Yes	1	No	243
9	O2	pwr4	pwr4	auto	novector	Yes	Yes	2	No	239
10	O2	pwr4	pwr4	auto	novector	Yes		0	Yes	227

After optimization of the cache and introducing the order O2 compiler f77 the time is approximately reduced by three from more than 600 to 227 seconds for one day with timestep of 900 s (Table 1). Thus, execution time of the simulations is less than four minutes for *the integrated system, i. e. assimilation plus hydrodynamics plus biochemistry*.

Biochemical preliminary results

The first test run starts from null initial velocities, and ends after 20 days of simulation. Figure 1 shows that, even starting from homogeneous conditions, this

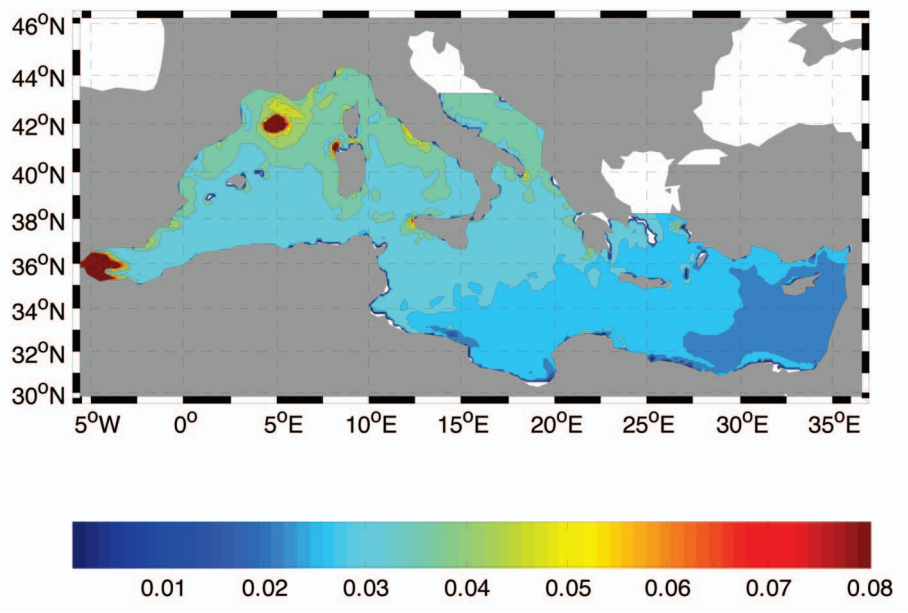

FIGURE 1. – *Nitrate concentrations (μMol N/l) in the first* 10 *m after* 20 *days of simulation.*

situation is broken after few days and maxima of nutrients are clearly seen in some cyclonic areas and in the Alboran area.

The biochemical initial conditions are the same as in Crispi et al. (1998)([2]) The forcing starts at the first of February 2000.

After 21 days of simulation there is an unrecoverable error and the run abends. The bug has been identified in some divisions by zero parameter in treelib.F library. After controlling this point, the above mentioned test job spanning 70 days correctly terminates the execution.

Assimilation experiment

The optimised integrated version, ported from SGI to IBM, is modified for interfacing and assimilating biomass data. The NPZD model evolution from the 1 September to 29 December 1998 is the originator of the assimilated data. Three runs are considered: reference, free, assimilation [1]. Weekly surface averaged data of phytoplankton, coming from the reference run, are assimilated.

The forcing functions are the 1998 winter daily forcing. Mean nitrate summer conditions are extracted from the Mediterranean climatology[5]. Averaged values are interpolated at 31 vertical levels of the model. This final profile initializes nitrate variable for all the Mediterranean basin.

Assimilation experiment and phytoplankton total contents are represented in Figure 2.

In the reference run, total phytoplankton increases gently from the initial value, reached at the end of the adjustment period, toward higher values, and after these maxima obtained approximately at the end of February, it decreases.

The free run gives a completely different behaviour: starting from quite low values, due to the summer biomass conditions injected at the beginning of the run, it has a very fast step in the first 40 days toward maxima of the same order in the reference run; at the end of the 70 days period, distinct higher values are attained.

In the assimilation run, the steps toward maxima every seven days, i. e. at assimilation times, are even more pronounced than in the free run, getting facilities from the statistical optimal interpolation procedure; in every case, at the end of the twin experiment lower values than free run ones are reached. Thus the biomass data assimilating evolution is closer to the “true ocean” response than the free one.

This scheme of resolution of the ecological processes has been used in the Toward Environmental Prediction Phase of the Mediterranean Forecasting System Project - MFSTEP. The objective is to assimilate experimental satellite and in situ biomass data in the ecosystem through SOFA, evaluating the performances of this scheme.

[5] B. Manca, M. Burca, A. Giorgetti, C. Coatanoan, M. J. Garcia and A. Iona, 2004. Physical and biochemical averaged vertical profiles in the Mediterranean regions: an important tool to trace the climatology of water masses and to validate incoming data from operational oceanography. J. Mar. Syst., 48(1-4), 83-116.

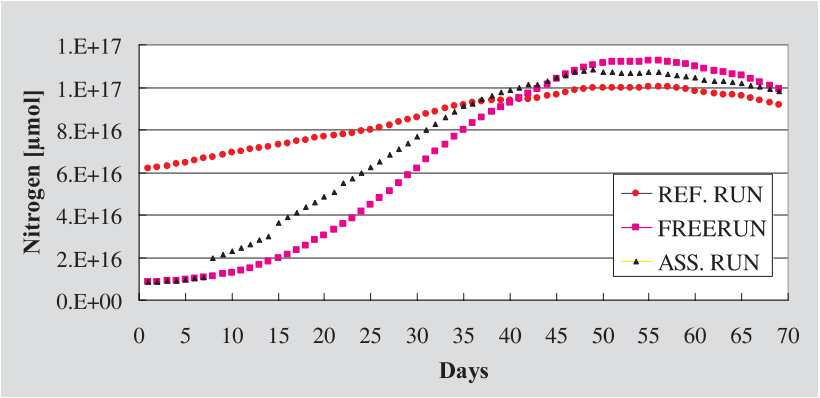

FIGURE 2. – *Basin average phytoplankton (µmol N) evolution in the* 70 *days of the three runs. Red diamond is the Reference run, violet square the Free and black triangle the Assimilation one.*

Long-term dynamics

The overall system requires that all the variables be in dynamical balance and that the total content be stable on average along the integration times. This part of refinement of the model requires realistic atmospheric loads, fractionated in its organic and inorganic components [2].

Terrestrial inputs are assigned on the basis of yearly average of nitrogen loads for the Gulf of Lions and Nile delta. These sources of nitrate are distributed in the area of the Rhone river mouth and in front of the Nile delta. For giving an insight in the method a simulation with more than thirty-three years is run, following the processes at the times of the Mediterranean basin. Stable situations are reached in the upper layers, 0-180 m, and in the intermediate ones, 180-420 m. Western Mediterranean diverts toward mesotrophic condition, while Eastern Mediterranean maintains the oligotrophic initial condition given all over the basin to the ecosystem. The deeper water contents are at the same extent pushed toward their equilibrium values.

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Publications

[1] G. CRISPI, and M. PACCIARONI, 2004. Reduced-order optimal interpolation for biomass data assimilation. Project MFSTEP WP6-D5. OGS Report/OGS-26, pp. 40.

[2] G. CRISPI, and M. PACCIARONI, 2005. Towards the nitrogen balancing of the Mediterranean Sea: perspective through combinations of load estimates and ecosystem modelling. IMEMS 2005 Seminar Proceedings. Ecological and Food Web Modeling, 18.