The Mediterranean ocean Forecasting System

Tonani M.[1], N.Pinardi[2], M.Adani[1], A. Bonazzi[1], G.Coppini[1], M.De Dominicis[1], S.Dobricic[3], M.Drudi[1], N.Fabbroni[1], C.Fratianni[1], A.Grandi[1], S.Lyubartsev[1], P.Oddo[1], D.Pettenuzzo[1], J.Pistoia[1] and I.Pujol[1]

[1]Istituto Nazionale di Geofisica e Vulcanologia, Gruppo di Oceanografia Operativa, via A. Moro 44, 40128 Bologna, Italy

[2]Alma Mater Studiorum Università di Bologna
Centro Interdipartimentale per la Ricerca sulle Scienze Ambientali,
Via S. Alberto 163, 48100 Ravenna, Italy

[3].Centro Euro-Mediterraneo per i Cambiamenti Climatici, via A. Moro 44, 40128 Bologna, Italy

* Corresponding author, email: tonani@bo.ingv.it

Abstract

The Mediterranean Forecasting System (MFS) is operationally working since year 2000 and it is continuously improved in the frame of international projects. The system is part of the Mediterranean Operational Oceanography Network-MOON and MFS is coordinated and operated by the Italian Group of Operational Oceanography (GNOO).

The latest upgrades and integration to MFS has been undertaken in the EU-MERSEA and BOSS4GMES Projects. Since October 2005 ten days forecasts are produced daily as well as 15 days of analyses once a week. The daily forecast and weekly analysis data are available in real time to the users through a dedicated ftp service and every day a web bulletin is published on the web site (http://gnoo.bo.ingv.it/mfs). A continuous evaluation in near real time of the forecasts and analyses produced by MFS has been developed in order to continuously verify the system and to provide useful information to the users. The R&D is focused on different aspects of the system. A new basin scale ocean model nested with operational MERCATOR global model has been developed and run in real time operationally for a test period together with a new assimilation scheme based on the 3DVAR. This system is now under evaluation. Important activities have been carried out to: implement and test a Bayesian methodologies of Ensemble and Super-Ensemble for the Mediterranean sea; produce 20 years of re-analysis; re-formulate the air-sea fluxes bulk formulae; develop dedicated products to support particular request of end users such as: indicators, real time oil spill forecasting, search & rescue.

Keywords:

Mediterranean Sea, Forecast, validation

1. Introduction

The Italian Group of Operational Oceanography (GNOO) at INGV has developed and maintains a system of ocean forecast for the Mediterranean sea. GNOO has the aim to coordinate the Italian activity in the frame of the operational oceanography. The system MFS is therefore part of the GNOO activities and has been developed in 1999 in the frame the EU-project MFSPP (Mediterranean Forecasting System Pilot Project) and MFSTEP (Mediterranean Forecasting System Toward Environmental Prediction) and has been further developed in the frame of MERSEA (Marine EnviRonment and Security for the European Area) and BOSS4GMES (Building Operational Sustainable services for GMES).

The system produces short term ocean forecast for the next ten days and since September 2005 the production is on a daily basis, while before it was weekly (Pinardi et al., 2003) and it is off-line coupled with a biogeochemical forecasting system (http://poseidon.ogs.trieste.it/cgi-bin/opapech/mersea).

2. Mediterranean Forecasting system

The system is producing every day (J) ten days of forecast from J to J+9, as shown by Fig. 1. On Tuesday 15 days of analyses are produced, from J-15 to J-1, with the assimilation of all the available satellite and in situ data. A biogeochemical forecast for the next ten days is produced every week on Tuesday by an off line coupling with an ecosystem model. All the day but Tuesday a 24hr simulation is performed (from J-1 to J) in order to get the best initial condition for the forecast. The simulations are forced with atmospheric analyses fields.

Every day the forecast is release with less then 10 hours delays.

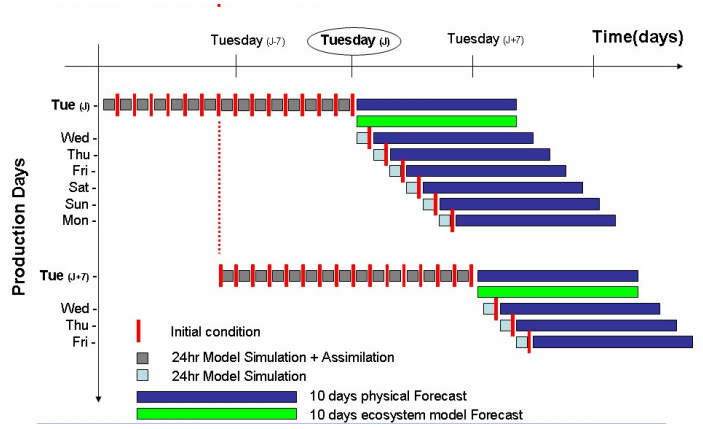

Figura 1: MFS production cycle.

2.1 Model and Data Assimilation Scheme

The MFS forecast system production is done using an OGCM implemented on the Mediterranean Sea and an assimilation scheme able to assimilate all the available in situ

and satellite data. At present two different systems, V1 and V2 are running in parallel every day. V1 is the official one while V2 is under evaluation. V1 is composed by the numerical code of OPA8.2 implemented on the Mediterranean sea (Tonani et al., 2008) and SOFA as sub optimal assimilation scheme (Dobricic et al. 2007). V2 uses NEMO as numerical model and 3DVAR for the assimilation. The major differences between the two systems are the boundary in the Atlantic ocean which are closed in V1 while are nested into GLOBAL –MERCATOR in V2 and the parameterisation of the water flux. The water flux is a relaxation to the climatological surface salinity in V1 while it is function of evaporation, computed from 6hr ECMWF fields, monthly climatology of precipitation from CMAP and river run off (Raicich, 1994 and Global Runoff Data Center) and input from Dardanells (Kourafalou, 2003) in V2. Table 1 reassumes the differences between V1 and V2.

Tabella 1: v1 and v2 main characteristics.

	V1	**V2**
OGCM numerical code	OPA8.2	NEMO
Atlantic boundaries	Close	Open (nested in Global MERCATOR)
Topography		Partial steps
Water Flux	Relaxation to climatological surface salinity	E-P-R
Assimilation Scheme	SOFA	3DVAR

2.2 MFS validation

The evaluation section of the web bulletin of MFS (http://gnoo.bo.ingv.it/mfs) is updated every Wednesday. The evaluation consists of the RMSE between the data and the analysis before the assimilation of the data into the system The RMSE is computed for the SLA, and the vertical profile of temperature (from argo and xbt) and salinity (from argo) at the selected depths of 8, 30, 150, 300 and 600m. Figure 2. shows in the left panel the values of RMSE for SLA from August 2004 to may 2008 and in the right panel the numbers of available data. The same visualisation is done for temperature and salinity at the different depths. The mean value of RMSE for SLA is around 4cm and is almost always below the value of 5 cm.

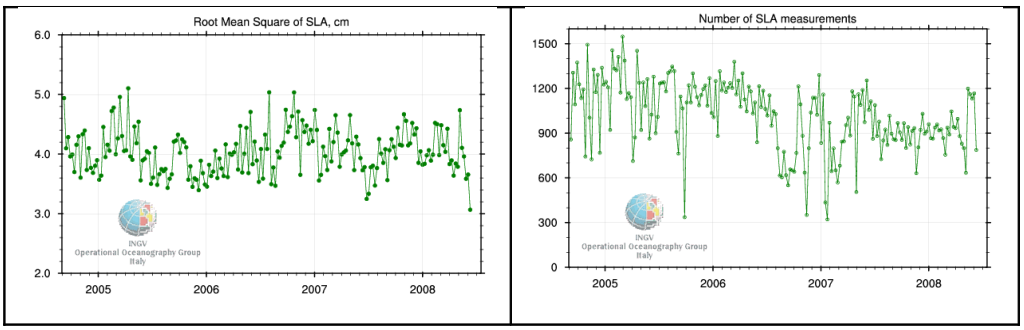

Figura 2: RMSE of SLA from August 2004 up to June 2008 and number of SLA measurements.

An evaluation procedure based upon totally independent data from ocean buoys is in a pre-operational set-up. The data from all the available oceanographic buoy in the Mediterranean sea have been collected for a determined period (years 2005 and 2006) for a preliminary comparison with MFS analyses and forecasts. The evaluation is done for temperature, salinity and currents. Figure 3 shows the results of this preliminary study at a buoy of Puertos del Estado close to the Spanish coast at Capo de Gata. The salinity from the buoy is compared with the fields of the MFS analysis and forecast in the model grid points closest to the position of the buoy. A weighted mean among the four closest point is then compared with the data from the buoy. The data from the buoy are not continuous over all the considered period but cover most of it. It's clear from the picture that is same period of the year the MFS match pretty well the buoy while in some others there could be differences of 0.3-0.4 psu like in the period at the end of December 2005 and February 2006. Soon this evaluation with totally independent data will be operational in near real time and will give the opportunity to evaluate the MFS system in NRT and continuously.

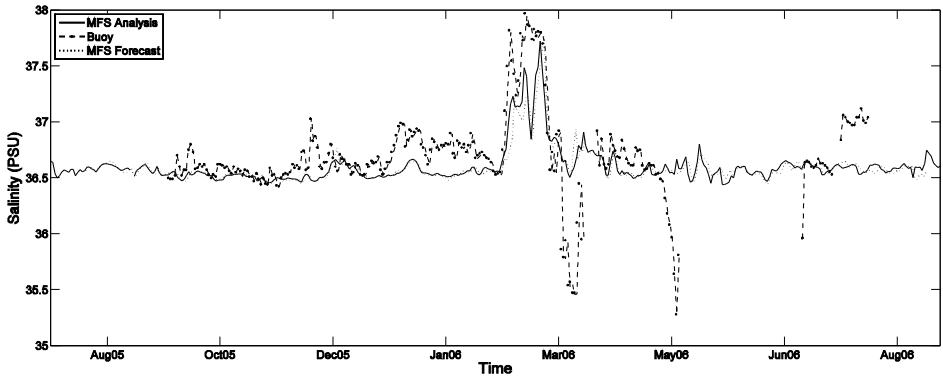

Figura 3: comparison of surface Salinity at Capo de Gata between a buoy from Puertos del Estado and MFS analysis and forecast for one year, (august 2005-August 2006).

3. Research & Development

The MFS system in constantly updated due to the research activities of the GNOO-INGV group. The ongoing research activities are described in the following paragraph.

3.1 Re-analyses

A 20 years re-analysis of the Mediterranean Sea has been performed, using the MFS system. Two experiments have been performed using the two different assimilation scheme: Reduced Order Optimal Interpolation (Sofa,Benkiran and DeMey, 2002) and

3DVAR (Dobricic and Pinardi, 2008) in order to evaluate the performance of the two different algorithms. The results show that both the assimilation schemes are capable in correcting the solution provided by the dynamical model and both the systems are able to retain the information and to project formally into the future. Even thought the two configurations have good capabilities in correcting the solution, 3dvar has demonstrated better skill. Therefore the 3dvar experiment has been performed for all the considered period.

3.2 Ensemble forecast

A new method has been devised for ensemble ocean forecasting using the probability distribution of the wind forcing as derived from a Bayesian Hierarchical Model (BHM). The BHM model exploits the information contained in QuikSCAT wind observations and stochastically represents the wind uncertainty that is found at the small spatial scales of ECMWF analyses. Ocean members are forced with samples from the posterior distribution of the wind during the assimilation of satellite and in-situ data to produce perturbed forecast initial conditions that are consistent with all ocean data. The ocean ensemble forecast is then produced for a 10 day period. The ocean ensemble statistical properties are used to investigate the predictability of short term ocean forecast. The on-going research activities are aimed to implement the ocean ensemble system within end-user applications that strongly require the evaluation of forecast errors.

3.3 Air-sea fluxes bulk formulae

Studies on air-sea interactions have been performed in order to improve the MFS capability to properly reproduce the heat and water budget of the Mediterranean Sea. This preliminary work consists of a set of corrections to the ECMWF ERA-40 atmospheric fields data computed through comparison with more reliable data sets. The biggest improvement on the total heat budget is obtained by means of the wind speed corrections through comparison with satellite vectors wind from QSCAT (Chin et al, 1998). The second main effort is the use of the ISCCP-FD radiation data set for both the downward components of the radiation. Other adjustments have been applied to the SST, using the optimal interpolated sea surface temperature (OI-SST) (Marullo et al, 2007), and to the computed specific humidity by the addition of an offset useful for the elimination of a low bias determined by comparison with NOC climatology (Josey, 1998). Moreover the bulk formulae used by MFS for the long and short wave radiation have been re-formulated. The results of this work are under assessment.

4. Application

MFS has developed different kind of downstream products based on the core services. Indicators have been defined in the frame of ETC-Water and B4GMES and are operationally produced. Every day is published a web bulletin which contains 7 years time series and daily maps of SST, heat content and transports. Forecast currents fields, which force a trajectory model have been used in support to search & rescue operations in collaboration with the Italian Coast Guard. A coupled MFS-MEDSLICK system is operationally used for oil spill forecasting in support to REMPEC activities.

5. Conclusion

The MFS system is operational since year 2000 and produced a short term forecast for all the Mediterranean basin. The system is constantly improved and evaluated in order to provide a good product to the users.

References

Chin T.M., R.F. Millif and W.G. Large (1998). Basin-scale, high-wavenumber sea surface wind fields from a multiresolution analysis of scatterometer data, J. of Atmospheric and Oceanic Technology, 15(3), 741-763.

Dobricic S., N. Pinardi, M. Adani, M. Tonani, C. Fratianni, A. Bonazzi, V. Fernandez, (2007). Daily oceanographic analyses by the Mediterranean basin scale assimilation system, Ocean Science., 3, 149-157.

Dobricic S., N. Pinardi, M. Adani, A. Bonazzi, C. Fratianni and M. Tonani, (2004). Mediterranean Forecasting System: a new assimilation scheme for sea level anomaly and it's validation, Q.J.R. Meteorol. Soc., 128, 1-12.

Josey S.A., E.C. Kent and P.K. Taylor (1998). The Southampton oceanographic centre (SOC) ocean-atmosphere heat, momentum and freshwater flux atlas, Technical Report.

Kourafalou V.H. and K. Barbopoulos (2003). High resolution simulations on the North Aegean Sea seasonal circulation, Ann. Geophysicae, 21, 251-265.

Manzella G.M.R., E. Scoccimarro, N.Pinardi and M. Tonani, (2003). Improved near real-time data management procedures for the Mediterranean ocean Forecasting System-Voluntary Observing Ship Program, Annales Geophisicae, 21, 1, 49-62.

Marullo S., B. Buongiorno Nardelli, M. Guarracino and R. Santoleri, (2007). Observing the Mediterranean sea from space: 21 years of phatfinder-avhrr sea surface temperature (1985 to 2005): re-analysis and validation, Ocean Science, 3, 299-310.

Pinardi N., I. Allen, E. Demirov, P. De Mey , G. Korres, A. Lascaratos, P.-Y. Le Traon, C. Maillard, G. Manzella, and C. Tziavos, (2003). The Mediterranean ocean forecasting system: first phase of implementation (1998–2001). Annales Geophysicae, 21: 3–20 c

Pinardi N., M.Adani, A. Bonazzi, A. Col uccelli, G. Coppini, S. Dobricic, V. Fernandez Lopez, C. Fratianni, S. Lunghi, F. Marzocchi, P. Oddo, M. Tonani and MFSTEP partners. Mediterranean Forecasting System Toward Environmental Prediction MFSTEP: status of implementation. Proceedings of the fourth EuroGOOS conference 6-9 June 2005, Brest (France). In press

Pinardi N., E. Demirov, M. Tonani,L.Giacomell,C.Fratianni and MFSPP partners, 2002. Mediterranean Ocean Forecasting System: first phase of implementation. Proceedings of the second international Conference on EuroGOOS 11-13 march 1999, Rome. EuroGOOS Publication No.17, Elsevier, Amsterdam

Raicich F. (1994). Note on the flow rate of the Adriatic Rivers, CNR-Technical Report, 02.

Tonani M., N.Pinardi, S. Dobricic, I. Pujol and C. Fratianni, (2008). A High Resolution Free Surface Model on the Mediterranean Sea. Ocean Science, 4, 1-14.