The Mediterranean ocean Forecasting System

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Abstract

The Mediterranean Forecasting System (MFS) is working operationally since 2000 and is being continuously improved through the framework 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 integrations to MFS have been undertaken in the EU MERSEA and BOSS4GMES projects. Since October 2005, 10-day forecasts have been produced daily as well as 15-day analyses once a week. The daily forecast and weekly analysis data are available in real time to 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 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 requests of end users such as: indicators, real time oil spill forecasting, search and rescue.

Keywords: Mediterranean Sea, forecast, validation

1. Introduction

The Italian Group of Operational Oceanography (GNOO) at INGV has developed and maintains a system for ocean forecasting for the Mediterranean Sea. GNOO aims to

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coordinate Italian activity in the field of operational oceanography. The MFS is therefore part of the GNOO activities and has been developed since 1999 through the EU projects MFSPP (Mediterranean Forecasting System Pilot Project) and MFSTEP (Mediterranean Forecasting System Toward Environmental Prediction) and has been further developed within MERSEA (Marine EnviRonment and Security for the European Area) and BOSS4GMES (Building Operational Sustainable services for GMES).

The system produces short-term ocean forecasts 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 also coupled off-line with a biogeochemical forecasting system (poseidon.ogs.trieste.it/cgi-bin/opapech/mersea).

2. Mediterranean Forecasting System

Every day (J) the system produces 10 days of forecast from J to J+9, as shown in Figure 1. On Tuesdays, 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 10 days is produced every week on Tuesdays using an off-line coupling with an ecosystem model. All days except Tuesdays a 24-hour 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 analysis fields.

The forecast is released every day with less then a 10-hour delay.

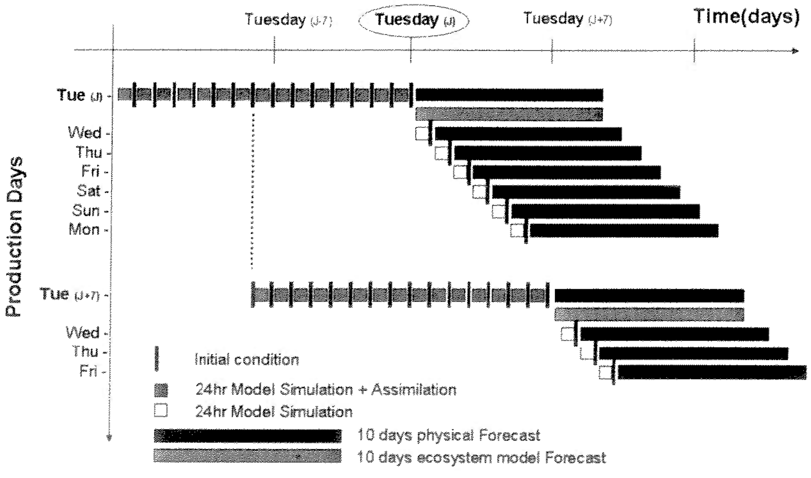

Figure 1 MFS production cycle.

2.1 Model and Data Assimilation Scheme

The MFS forecast system production is made 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, run in parallel every day. V1 is the official system while V2 is under evaluation. V1 uses the numerical code of OPA8.2 implemented on the Mediterranean Sea (Tonani *et al.*, 2008) and SOFA as a sub-optimal assimilation scheme (Dobricic *et al.* 2007). V2 uses NEMO as a numerical model and 3DVAR for the assimilation. The major differences between the two systems is that the boundary for the Atlantic ocean is closed in V1 whereas in V2 it is open, taking values from the GLOBAL-MERCATOR model, and the parameterisation of the water flux. The water flux is a relaxation to the climatological surface salinity in V1 while it is a function of evaporation, computed from 6-hour 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 summarises the differences between V1 and V2.

Table 1 V1 and V2 main characteristics

	V1	V2
OGCM numerical code	OPA8.2	NEMO
Atlantic boundaries	Closed	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 MFS web bulletin (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 floats and XBTs) and salinity (from Argo floats) at the selected depths of 8, 30, 150, 300 and 600 m. The left panel of Figure 2 shows the values of RMSE for SLA from August 2004 to May 2008 and the right panel shows the number of available measurements. The same overview is presented for temperature and salinity at the different depths. The mean RMSE for SLA is around 4 cm and is almost always below the value of 5 cm.

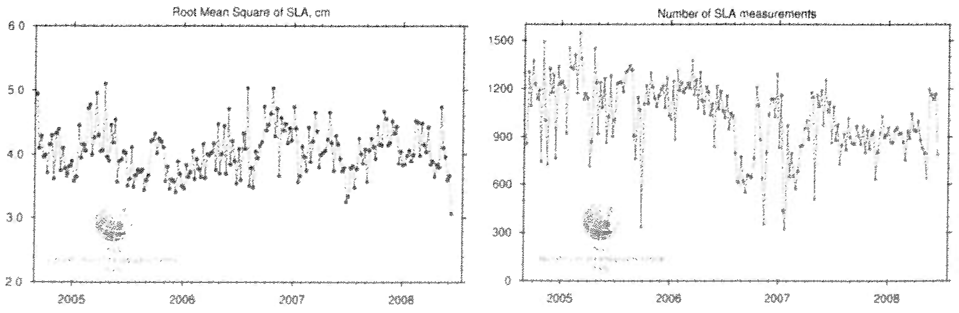

Figure 2 RMSE of SLA from August 2004 up to June 2008 and number of SLA measurements.

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 buoys in the Mediterranean Sea have been collected for a determined period (the years 2005 and 2006) for a preliminary comparison with MFS analyses and forecasts. An evaluation is made for temperature, salinity and currents. Figure 3 shows the results of this preliminary study at a Puertos del Estado buoy close to the Spanish coast at Capó 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 points is then compared with the data from the buoy. The data from the buoy are not continuous over the whole period but cover most of it. It is clear from the picture that for some periods the MFS model matches the buoy data quite well while in some other periods there could be salinity differences of 0.3–0.4, for example 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 provide the opportunity to evaluate the MFS system continuously in near real-time.

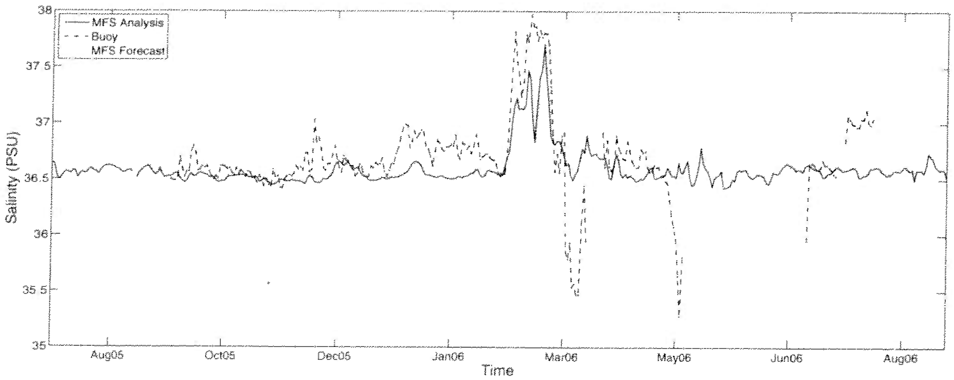

Figure 3 comparison of surface salinity at Capo de Gata between a buoy from Puertos del Estado and MFS analysis and forecast for the year August 2005 – August 2006.

3. Research and development

The MFS system is continuously being updated due to the research activities of the GNOO–INGV group.

3.1 Re-analyses

A 20-year re-analysis of the Mediterranean Sea has been performed, using the MFS system. Two experiments have been carried out using two different assimilation schemes: Reduced Order Optimal Interpolation (Sofa, De Mey and Benkiran, 2002) and 3DVAR (Dobricic and Pinardi, 2008) in order to evaluate the performance of the two different algorithms. The results show that both assimilation schemes are capable of correcting the solution provided by the dynamic model and both the systems are able to retain the information and to project formally into the future. Even though the two configurations have good capabilities in correcting the solution, 3DVAR has demonstrated better skill. Therefore the 3DVAR experiment has been carried out for the entire 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 aim to implement the ocean ensemble system within end-user applications that strongly require the evaluation of forecast errors.

The ensemble size is set to 10 members due to technical constraints. However in previous studies, e.g. Dobrocic and Pinardi (2008), the short term ocean forecasting for low predictability regions identified by small size ensembles show similarities to low predictability regions identified by larger ensembles.

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 field 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 vector winds from QSCAT (Chin *et al.*, 1998). The second main effort is the use of the ISCCP-FD (International Satellite Cloud Climatology Project – Flux Data) 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 long and short wave radiation have been re-formulated. The results of this work are under assessment.

4. Application

MFS has developed different kinds of downstream products based on the core services. Indicators have been defined in the frame of ETC-Water (European Topic Centre on Water) and BOSS4GMES and are operationally produced. A web bulletin is published every day which contains 7 years of time series and daily maps of SST, heat content and transports. Forecast currents fields, which force a trajectory model have been used in support of search and rescue operations in collaboration with the Italian Coastguard. A coupled MFS-MEDSLICK system is operationally used for oil spill forecasting in support to REMPEC (Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea) activities.

5. Conclusion

The MFS system has been operational since 2000 producing short-term forecasts for the Mediterranean basin. The system is constantly being improved and evaluated in order to provide a good product to the users.

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