Comment on egusphere-2022-1337

Anonymous Referee #2

Referee comment on "The Mediterranean forecasting system. Part I: evolution and performance" by Giovanni Coppini et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-1337-RC2, 2023

Comments of the Referee are in black while the authors' reply is in red.

The manuscript content is mostly technical. It presents the main steps taken to construct a complex operational ocean forecasting for the Mediterranean Sea, which contains physical, wave and biogeochemical components. It should be highlighted that each component has its own data assimilation system, so that important effort was made to extract the most relevant information from observations to benefit the system forecasting skills. The main goal of the paper is to present the current quality of the operational system components by comparing the analysis and - for specific variables, such as significant wave height - the background (forecast) with observations, in situ and/or by satellites. In the text (L350) it is made clear that only the analyses will be evaluated and that the system short-range predictability will be assessed in a future work. However, the WAV and BIO components were also verified by using the background, i.e., the short- range prediction. Please, provide the adequate information with respect to this emphasis.

We thank the reviewer for the comments. We propose to add the following text to clarify this aspect: "Each component of the Med-MFC has its own data assimilation system, so that important effort was made to extract the most relevant information from satellite and in situ observations to produce analysis and correct initial conditions for the forecast in order to benefit the forecasting skills. The main goal of the paper is to present the current quality of the operational system components by comparing the analysis and - for specific variables, such as significant wave height - the background (simulation) with observations, in-situ and/or satellites. The skill of the wave and biogeochemical models is assessed by considering inter-comparisons of the model solution during the 24-h analysis phase with in-situ and remotely sensed observations. As the latter are ingested into the model through data assimilation, the first guess model fields (i.e. model background) are used instead of analyses."

The text is very well written and contains a broad range of references to works that led to the forecasting system construction. However, it would be useful to add a new reference, by Napolitano et al. 2022, (https://doi.org/10.3389/fenrg.2022.941606) about a physical and wave forecasting system for the Mediterranean Sea that uses the MED system as initial condition and lateral boundary condition. It is another relevant use to MED system.

We thank the reviewer for the comment and we propose to add the following text after Line 554 to include information on several systems using the Med-MFC products for downscaling purposes: "The value and reliability of the Med-MFC systems is demonstrated by the several downscaling coastal model systems and downstream applications that use its outputs operationally. The CYCOFOS – Cyprus Coastal Ocean Forecasting and Observing System (Zodiatis et al 2003), which is a sub-regional forecasting and observing system in the Eastern Mediterranean Levantine Basin, uses the Med-MFC output to set its boundary conditions. The Med-MFC outputs are used for initial and lateral boundary conditions by the physical and wave ocean system MITO, which provides 5-day forecasts at resolution up to 1/48° (Napolitano et al., 2022). The Southern Adriatic Northern Ionian coastal Forecasting System (SANIFS), which is a coastal-ocean operational system providing short-term forecasts since September 2014 (Federico et al, 2017). It is built on the unstructured-grid finite-element three-dimensional hydrodynamic SHYFEM model and is based on a downscaling approach starting from the large-scale system Med-MFC which provides the open-sea fields.

The CADEAU physical-biogeochemical forecast system of the Northern Adriatic Sea (Bruschi et al., 2021) is based on a high resolution (up to 700m) application of the MITgcm-BFM model (Cossarini et al., 2017) targeting water quality and eutrophication and uses the daily Med-MFC products for initialization and to constrain the southern boundary."

Please, it would be useful if more information is offered about the 2 way coupling between NEMO and WW3 and the wind forcing (L110). Does the speed of the ocean currents are considered to calculate the vertical momentum flux? Clementi et al (2017) paper is referred to for more information, but if you could give here this information it would be useful.

We thank the reviewer for this comment which will help us to better explain our coupling approach. The 2-way coupling is only implemented between NEMO and WW3 and the two models are forced (but not coupled) by the same atmospheric fields (ECMWF high resolution). To better explain the coupling strategy, the text at Line 110 will be modified as follows: “The exchanges between the circulation and wave models are performed using an online two-way coupling between NEMO and WW3. The models are forced by the same atmospheric fields (high resolution ECMWF analysis and forecast winds) and are two-way coupled at hourly intervals exchanging the following fields: NEMO sends to WW3 the sea surface currents and temperature which are then used to evaluate the wave refraction and the wind speed stability parameter, respectively. The neutral drag coefficient computed by WW3 is passed to NEMO to compute the surface wind stress.”

Also, despite using the monthly climatology for the river runoff inputs, the salinity at the river mouths are kept constant along time. Are there measurements that corroborate to this condition? At least at the mouth of the rivers with the largest fluxes, do you know about salinity variability from intraseasonal to interannual scales. Please, include a phrase commenting this condition.

Measurements of salinity at river mouths are very few and usually do not cover a long period of time. It is known that the salinity at river mouths is not constant in time, but an evaluation of the seasonal and interannual variability based on salinity observations is not possible due to lack of observations. Thus the values of the salinity at river mouths have been evaluated by means of sensitivity experiments in the context of Delrosso (2020) PhD thesis and kept constant in time. These values will be improved once an estuary box model, such as the one presented in Verri et al. (2020), will be implemented and coupled to the hydrodynamic model to retrieve more realistic and time varying values.

Following the reviewer’s comment, the sentence at Line 127 will be integrated as follows:

“The river runoff inputs consist of monthly climatological data for 39 major rivers (characterized by an average discharge larger than 50 m3/s) with a prescribed constant salinity at river mouth (Delrosso, 2020) evaluated by means of sensitivity experiments and listed in Table A.4. More realistic and time varying river salinity values (at least for major rivers) will be evaluated in future modeling evolutions using an estuary box model, such as the one presented in Verri et al. (2020), coupled to the hydrodynamic model.”

A new reference will be then added:

Verri, G., Pinardi, N., Bryan, F., Tseng, Y., Coppini, G., and Clementi, E.: A box model to represent estuarine dynamics in mesoscale resolution ocean models. Ocean Modelling. http://dx.doi.org/10.1016/j.ocemod.2020.101587, 2020

With respect to the data assimilation systems employed in the PHYS, WAV and BIO components, is superob utilized? Does the system has this capability? It is very common the use of superob for the high resolution SST or longwave radiation data and SLA data.

Please, mention in a short phrase if it is employed or not and why.

We thank the reviewer for this comment which will help to provide further details on the data assimilation used.

In the PHY system, we do not perform superobing for observations but a subsampling is applied for the SLA tracks. SST is relaxed to a gridded product therefore it is treated separately from the assimilated observations. To clarify the issue we add the below phrase in paragraph starting at Line 149: “The SLA tracks provided by nadir altimeters are assimilated by subsampling every second observation in order to reduce the spatial correlation between consecutive measurements.”

In the WAV system, available SWH observations are collocated with the closest grid point and averaged. The following phrase will be added at Line 225: “Prior to OI procedure, quality checked SWH observations which are available in a ±1.5 hours time window are collocated with the closest model grid point and averaged.”

The BIO model system assimilates surface chlorophyll from Ocean Color product that is previously interpolated from the original resolution of 1km to the model resolution of 1/24°. The sentence at Lines 287-288 will be modified as following: "In the most recent BIO model configuration (Teruzzi et al., 2021, Cossarini et al., 2019), the assimilated biogeochemical observations are satellite multi-sensor (MODIS, VIIRS and OLCI) surface chlorophyll data (Volpe et al., 2019) and quality-controlled Argo-289 BGC nitrate and chlorophyll profiles (Schmechtig et al., 2018; Johnson et al., 2018). Ocean color data are interpolated from original 1km resolution to the 1/24° model resolution.

You mention that in WAV forecasting cycle, the model is initialized 24 h in the past. Do you use atmospheric analysis forcing during this past period?

The WAV system described in this work runs one cycle per day and simulates 264 hours (11 days): 24 hours in the past (analysis) blending - through data assimilation - model results with available SWH satellite observations from Copernicus WAVE satellite Near Real Time product and 10 days (240 hours) into the future (forecast mode). The assimilation step adopted in this scheme equals to 3 hours. During the analysis mode the system is forced with ECMWF analyses 6-hourly winds, while forecast ECMWF winds are used afterwards.

To clarify this issue at Line 195, the following will be added: "The WAV component runs one cycle per day operating in analysis (for 24 hours in the past - previous day) and forecast (for 10 days in the future) modes. During the analysis phase, model background is blended through data assimilation with available SWH satellite observations at 3-hourly intervals and forced with ECMWF analyses 6-hourly winds and daily averaged surface currents."

I did not understand very clearly the forecasting cycle of the BIO component. Could you please clarify how the nutrients, DIC and oxygen are initialized. You mention (L255) that climatological profiles are used in the model initial condition in each subregion of Fig 3. Does the assimilation of chlorophyl and Argo BCG data change these vertical profiles of nutrient, DIC and oxygen in each forecasting cycle?

For a subset of variables (nitrate, ammonia, silicate, phosphate, oxygen, alkalinity and DIC), the initial condition consists of 16 profiles homogeneously applied to all grid points of each of the 16 sub-regions of Fig. 3. The profiles are computed from the Emodnet dataset (Buga et al., 2018). The other biogeochemical state variables (phytoplankton, zooplankton and bacteria biomasses) are initialised in the photic layer (0–200 m) according to the standard BFM values (see BFM manual, Vichi et al., 2020). Then, a 5-year hindcast is run using the first year (i.e., 2017) in perpetual mode to smooth discontinuities among sub-areas (e.g., protocol described in Salon et al., 2019).

The sentence at Lines 255-256 will be revised as follows:

"Initial condition of nutrients (nitrate, ammonia, silicate and phosphate), oxygen and carbonate variables (DIC and alkalinity) consists of 16 climatological profiles homogeneously applied in each sub-region represented in Fig. 3 computed from the EMODnet dataset (Buga et at., 2018). The remaining biogeochemical state variables (phytoplankton, zooplankton and bacteria biomasses) are initialized in the photic layer (0–200 m) according to the standard BFM values. A 5-year hindcast is run using the first year (i.e. 2017) in perpetual mode."

Salon, S., Cossarini, G., Bolzon, G., Feudale, L., Lazzari, P., Teruzzi, A., et al.: Novel metrics based on Biogeochemical Argo data to improve the model uncertainty evaluation of the CMEMS Mediterranean marine ecosystem forecasts, Ocean Science, 15(4), 997-1022, 2019.

Vichi, M., Lovato, T., Butenschön, M., Tedesco, L., Lazzari, P., Cossarini, G., Masina, S., Pinardi, N., Solidoro, C., and Zavatarelli, M.: The Biogeochemical Flux Model (BFM): Equation Description and User Manual. BFM version 5.2. BFM Report series N. 1, Release 1.2, June 2020, Bologna, Italy, http://bfm-community.eu, pp. 104, 2002.

The figures are adequately prepared, but I miss a colorbar in Figs. 6 an 8. The work deserves publication, since it will be an important reference for the continuation of the evolution of the system.

We thank the reviewer for this comment. Colorbars representing the density of observations will be added in Figs 6 and 8 as presented below:

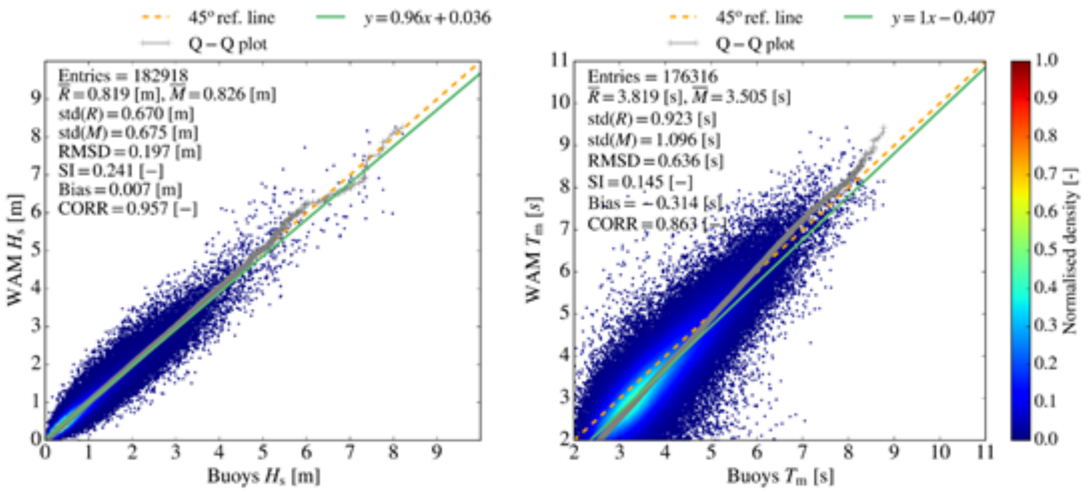

Figure 6

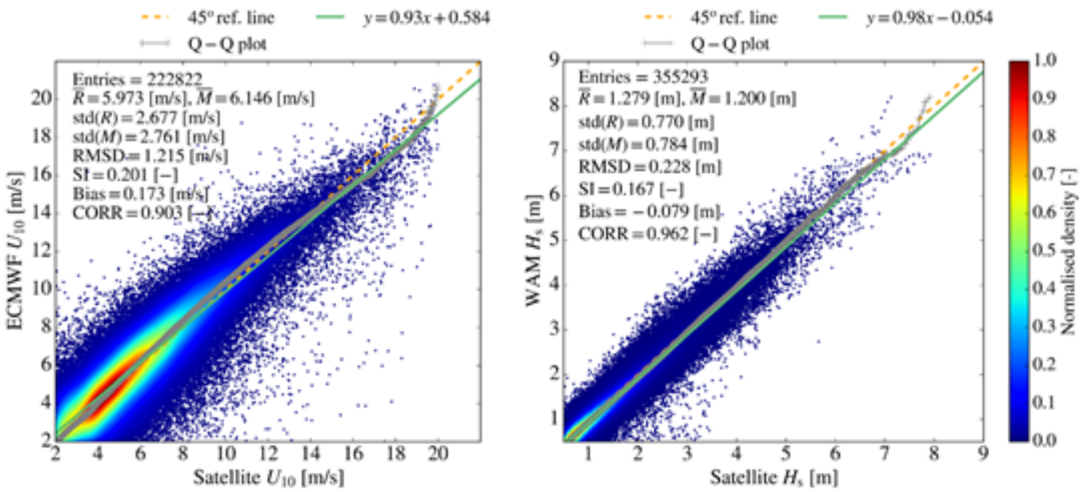

Figure 8

Minor comments

L46-47. Please, use MED-MFC or Med-MFC throughout the text. L65. The period 2017-2020 should be corrected to 2018-2020. L78. Include a reference for the OceanVar.

We thank the reviewer for the comment. We will correct the text using the same nomenclature (Med-MFC) and we will correct the period of validation and include a reference for the oceanVar.

L145-146 “SLA along track observations shallower than this depth are not assimilated”. I understand what you mean, but it would be better to rephrase as “SLA along track observations over waters shallower than this depth are not assimilated”.

We thank the reviewer for the comment. We will update the text accordingly in Lines 145-146 as follows: “A reference level of 1000 m is used for this operator so SLA along track observations over water shallower than this depth are not assimilated.”

L170-171. Please, fix the parenthesis used in the references.

We thank the reviewer for the comment. We will recheck all the references and fix the parenthesis.

L337-340. Please, you may use "three major improvements of the BFM model included: (i) the addition of ...; (ii) the revision of ... and so on.

We agree with the reviewer. The text at Lines 337-340 will be revised as following: "Since 2008, three major improvements of the BFM model have been integrated (i) the addition of the carbonate system to predict alkalinity, ocean acidity and CO2 air-sea exchanges in 2016 (Cossarini et al., 2015), (ii) the revision of nutrient formulation of phytoplankton in 2018 (Lazzari et al., 2016) and, (iii) in 2020, the introduction of the day-night cycle in light-dependent formulation of phytoplankton (Salon et al., 2019) and of the novel light extinction coefficient (Terzic et al., 2021)."

L357-359. Please, clarify what you mean by "daily mean analysis products". I understand you produce only one analysis per day with a single analysis increment at a specific time. Therefore, I do not understand how you can take daily means. You can take, for instance, annual means from daily outputs, but not daily means. In line 363, also refer to daily mean analysis.

The reviewer is right, we perform a variational analysis once a day and correct the state variables before reinitializing the model for the next analysis cycle. However, the term analysis in "daily mean analysis products" refers to the integration period in which we assimilate to differentiate it from a forecast in the operational context.

To avoid misunderstanding we rewrite the paragraph from Line 355 as follows:

"The skill of the physical component is assessed over a 3-year period from 2018 to 2020 (Clementi et al., 2019). The evaluation is done by means of Estimated Accuracy Numbers (EANs) which consist of the root mean square differences (RMSD) and bias (model minus observations) of daily mean of model outputs against satellite and in-situ observations. EANs are evaluated using daily mean of model estimates interpolated on the available observations in that day: this goodness score is somewhat approximated especially at the surface where daily variability is large, but this is a score used by many forecasting systems (Ciliberti et al., 2022; Toledano et al., 2022; Sotillo et al., 2021; Najy et al., 2020) and we will show it for reference purposes. We also use misfits, which are the difference between the model solutions and the observations at the observational time during the forward model integration, for this assessment. The misfits provide quasi-independent and more accurate skill assessment since they are calculated before the variational analysis and at the observational time."

L414. The skill of the WAV component is assessed both with the analysis and the background, but in L350-351 you have mentioned that the forecast skill would be assessed in a future work. Please, clarify the components that will be here evaluated only with analyses and with analyses and forecasts.

As for the other components of the Med-MFC system, the skill of the Mediterranean wave model is assessed by considering inter-comparisons of the wave solution during the 24-h analysis phase with in-situ (SWH and mean wave period from wave buoys) and remotely sensed (SWH) observations. As the latter are ingested into the model through data assimilation, the first guess model SWH fields (i.e. model background) are used instead of analyses. The text in Line 414 will be revised as follows: "The skill of the Mediterranean wave model is assessed by considering inter-comparisons of the model solution during the 24-h analysis phase with available in-situ (SWH and mean wave period from wave buoys) and remotely sensed (SWH) observations. As the latter are ingested into the model through data assimilation, the model first guess SWH (i.e. model background) is used instead of model analysis."

L431. Substitute "forcing wind model" by model wind forcing

The phrase "the spatial resolution of the forcing wind model" will be changed to "the spatial resolution of the wind forcing" in Line 431. Thank you.

L435. The unit is missing after 0.13

The unit (m) will be added after 0.13 in Line 435. Thank you.

L442. Remove "is" from the phrase "that ECMWF is forcing underestimates"

Line 442 will be revised following the reviewer's comment.

Table 6. Please, correct the entry Phosphate RMSD x 0-10 m and superscripts of the variables Phosphate and Ammonia. The unit of the layers (m) is also missing.

We thank the reviewer for spotting these oversights. A new version of Table 6 and its caption at Line 1204 is as follows:

"Table 6. RMSD of the difference between model and climatological profiles at different depths evaluated in the 2017-2020 reference period. Statistics are computed using the 16 sub-regions in Figure 3. Reference datasets for validation (last column) are: (1) EMODnet data collections (Buga et al., 2018) integrated with additional oceanographic cruises (Cossarini et al., 2015), and (2) Socat dataset (Baker et al 2014)."

Variable	**indicative range values**	**RMSD**								**data set**
		0-10m	**10-30m**	**30-60m**	**60-100m**	**100-150m**	**150-300m**	**300-600m**	**600-1000m**	
Phosphate [$mmol/m^3$]	0.01-0.70	0.03	0.03	0.027	0.023	0.043	0.028	0.040	0.027	1
Nitrate [$mmol/m^3$]	0.1-9.0	0.42	0.41	0.49	0.72	0.83	0.72	1.09	0.83	1
Ammonia [$mmol/m^3$]	0.01-1.23	0.41	0.17	0.15	0.23	0.30	0.32	0.44	0.54	1
Silicate [$mmol/m^3$]	0.1-7.0	1.5	1.5	1.3	0.9	0.9	0.7	0.7	0.8	1
Oxygen [$mmol/m^3$]	190-260	5.9	5.7	6.4	4.2	5.2	4.3	8.6	5.8	1
DIC [µmol/kg]	2100-2400	42.2	37.6	28.1	17.1	16.7	7.7	9.9	3.8	1
Alkalinity [µmol/kg]	2360-2730	41.7	34.4	26.0	19.1	12.5	12.1	9.0	7.0	1
pH	7.0-8.2	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.01	1
pCO2 [µatm]	250-550	46								2

L595. Replace WAB by WAV

Line 569 will be corrected as follows: “Also, for the WAV component, the development of a WAV ensemble prediction system will be necessary.” Thank you.