Copernicus Marine Service

QUALITY INFORMATION DOCUMENT

Mediterranean Sea Production Centre
MEDSEA_ANALYSISFORECAST_PHY_006_013

Issue: 2.4

Contributors: A.C. Goglio, E. Clementi, A. Grandi, A. Moulin, M. Giurato, A. Aydogdu, J. Pistoia, P. Miraglio, A. Mariani, M. Drudi

Approval date by the Copernicus Marine Service product quality coordination team: 14/11/2023

CHANGE RECORD

When the quality of the products changes, the QuID is updated, and a row is added to this table. The third column specifies which sections or sub-sections have been updated. The fourth column should mention the version of the product to which the change applies.

Issue	Date	§	Description of Change	Author	Validated By
1.0	25-09-2017	All	Release of EAS2 version of the Med-Physics analysis and forecast product at 1/24° resolution	E. Clementi, A. Grandi, P. DiPietro, J. Pistoia, D. Delrosso, G. Mattia	E. Clementi (Med-MFC Deputy)
1.1	18-01-2018	All	Release of EAS3 version of the Med-Physics analysis and forecast product at 1/24° resolution	E. Clementi, A. Grandi, P. DiPietro, J. Pistoia, D. Delrosso, G. Mattia	E. Clementi (Med-MFC Deputy)
1.2	28-01-2019	All	Release of EAS4 version of the Med-Physics analysis and forecast product at 1/24° resolution	E. Clementi, A. Grandi, R. Escudier, V. Lyubartsev	E. Clementi (Med-MFC Deputy)
1.3	06-12-2019	All	Release of EAS5 version of the Med-Physics analysis and forecast product at 1/24° resolution	E. Clementi, A. Grandi, V. Lyubartsev	E. Clementi (Med-MFC Deputy)
1.4	10-09-2020	II.1 II.2 II.3 V	Use of higher resolution ECMWF atmospheric forcing	E. Clementi, A. Grandi, J. Pistoia	E. Clementi (Med-MFC Deputy)
2.0	15-01-2021	All	Updated document for the new product: modeling system including tides	E. Clementi, A. Grandi, A.C. Goglio, A. Aydogdu, J. Pistoia, V. Lyubartsev	E. Clementi (Med-MFC Deputy)
2.1	10-09-2021	II, IV, V	Updated document for new upstream river data	E. Clementi, A. Grandi, A.C. Goglio	E. Clementi (Med-MFC Deputy)
2.2	01-12-2021	IV, V	Updated document for SST satellite upstream data change and delivery of updated timeseries	E. Clementi	E. Clementi (Med-MFC Deputy)
2.2.1	23-09-2022	III. 4, V	Updated document for upstream data change: SLA Sentinel-6A assimilation	E. Clementi, A. Aydogdu, A. Grandi, A.C. Goglio	E. Clementi (Med-MFC Deputy)

Issue	Date	§	Description of Change	Author	Validated By
2.3	02-09-2022	All	Model and data assimilation improvements	A.C. Goglio, A. Grandi, E. Clementi, A. Aydogdu, A. Mariani	E. Clementi (Med-MFC Deputy)
2.4	20-09-2023	All	Model and data assimilation improvements	A.C. Goglio, A. Grandi, E. Clementi, A. Aydogdu, A. Moulin, P. Miraglio, J. Pistoia	E. Clementi (Med-MFC Deputy)

TABLE OF CONTENTS

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I EXECUTIVE SUMMARY

I.1 Products covered by this document

The product covered by this document is the MEDSEA_ANALYSISFORECAST_PHY_006_013: the analysis and forecast nominal product of the physical component of the Mediterranean Sea with 1/24° (~4 km) horizontal resolution and 141 vertical levels.

The variables produced are:

- 3D daily, hourly and monthly mean fields of: potential temperature, salinity, and zonal, meridional and vertical velocities
- 2D daily, hourly and monthly mean fields of: sea surface height (SSH), sea surface zonal and meridional velocities, mixed layer depth (MLD), and seabed temperature (temperature of the deepest layer or level)
- 2D daily mean fields of: SSH de-tided, sea surface zonal and meridional velocities de-tided
- 15-minute instantaneous fields of: SSH and sea surface zonal and meridional velocities

Product reference:

Clementi, E., Drudi, M., Aydogdu, A., Moulin, A., Grandi, A., Mariani, A., Goglio, A. C., Pistoia, J., Miraglio, P., Lecci, R., Palermo, F., Coppini, G., Masina, S., & Pinardi, N. (2023). Mediterranean Sea Physical Analysis and Forecast (CMS MED-Physics, EAS8 system) (Version 1) [Data set]. Copernicus Marine Service (CMS).https://doi.org/10.25423/CMCC/MEDSEA_ANALYSISFORECAST_PHY_006_013_EAS8

I.2 Summary of the results

The quality of the MEDSEA_ANALYSISFORECAST_PHY_006_013 analysis and forecast product provided by the EAS8 modelling system, is assessed over the 2-year period from 01/01/2020 to 31/12/2021 by comparisons with observations of temperature, salinity, sea level anomaly, tidal sea level, currents, seabed temperature and mixed layer depth from independent (for surface currents and tidal sea level), quasi-independent satellite and in-situ observations, and climatological datasets as well as through inter-comparisons with the previous version of the MEDSEA_ANALYSISFORECAST_PHY_006_013 product timeseries, corresponding to the EAS7 modelling system.

The main results of the MEDSEA_ANALYSISFORECAST_PHY_006_013 quality assessment are summarized below:

Sea surface height: the EAS8 system presents a better accuracy in terms of SSH with respect to the previous version. The quality of the predicted Sea Level Anomaly (SLA) has been assessed by comparing model daily outputs and satellite along-track observations, yielding an average RMSD of 2.8 cm which is lower than the 3.0 cm obtained with the previous version. These values are based on the two-year period 2020-2021 used for the comparison. A harmonic analysis shows that the new system has a good skill in representing tidal amplitudes and phases of all the considered tidal constituents.

Temperature: compared to vertical in-situ observations, model temperatures exhibit an RMSD that never exceeds 0.86°C in any vertical layer (Table 1). For comparisons of model SST with L4 satellite observations, the RMSD does not exceed 0.84°C in any basin subregion (Table 2) (Figure 1). Vertically, temperature RMSD is higher in the top layers and decreases below 60 m. For SST, RMSD with respect to satellite observations vary across subbasins, ranging from 0.44°C to 0.84°C. The product usually exhibits a positive SST bias.

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Commented [ACG4R3]: The acronim is defined in the previous words (SLA = Sea Level Anomaly) while, the concept, is well defined and well known in the field. It is well explained in all manuals, books and papers.

Commented [EiC5R3]: It is stated in those words because I added them during my first edit.

Commented [EiC6]: As per MOI instructions, please avoid use of “error” terminology but use “difference” instead. E.g., RMSD instead of RMSE, MAD instead of MAE, etc. Use of “error” gives the (false) impression that satellite (or other) observations represent the prefect truth.

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Salinity: RMSD does not exceed 0.2 psu in any vertical layer (Table **3**). ~~The error~~ It is higher in the upper layers and decreases significantly below 150 m.

Currents: Surface current RMSD and bias are evaluated against moored buoys and available HF radars. Due to the small number of observations, mainly concentrated in coastal areas of the western part of the basin, the statistics for current performance are not very robust. In addition to assessing surface currents, we also assessed transport through straits including the net east- and westward transports through the Strait of Gibraltar, which showed good agreement with literature values in terms of net transport. The value of this last, estimated on a five-years period, is 0.039 Sv.

Bottom temperature: compared to SeaDataNet monthly climatologies, the model showed good skill in representing the seasonal variability of bottom temperatures, although yielding a warm bias. The spatial pattern of seabed temperatures is correctly represented by the system.

Mixed layer depth: compared to climatological estimates in the literature (Houpert at al., 2015) the model is capable to correctly represent MLD including its spatial and seasonal differences. In general, the main differences might be linked to the low resolution of the climatological dataset, which, in addition, does not cover the whole Mediterranean Sea.

I.3 Estimated Accuracy Numbers

Estimated accuracy numbers (EANs), namely bias and RMSD between model and in-situ or satellite observations, are provided in Tables 1-4.

EANs are computed for:

- Temperature;
- Salinity;
- Sea surface temperature (SST);
- Sea level anomaly (SLA).

The observations used are:

- vertical profiles of temperature and salinity from Argo floats: INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030
- SST satellite data from Copernicus Marine SST-TAC products:

  SST_MED_SST_L4_NRT_OBSERVATIONS_010_004 and SST_MED_SST_L3S_NRT_OBSERVATIONS_010_012
- Satellite sea level along-track data from Copernicus Marine SeaLevel-TAC products:

  SEALEVEL_EUR_PHY_L3_REP_OBSERVATIONS_008_061 and SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059

The EANs are evaluated for the EAS8 system over a two-year period from January 2020 to December 2021, and are computed for the whole Mediterranean Sea and its 16 sub-regions depicted in Figure 1: (1) Alboran Sea, (2) South West Med 1 (western part), (3) North West Med, (4) South West Med 2 (eastern part), (5) Tyrrhenian Sea 2 (southern part), (6) Tyrrhenian Sea 1 (northern part), (7) Ionian Sea 1 (western part), (8) Ionian Sea 2 (south-eastern part), (9) Ionian Sea 2 (north-eastern part), (10) Adriatic Sea 2 (southern part), (11) Adriatic Sea 1 (northern part), (12) Levantine Sea 1 (western part), (13)

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Commented [EiC12]: Consider including the actual values, as you did for the previous variables, as this summary should contain quantitative results as well.

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Commented [EiC17]: As there is more than 1 table, either use plural, or better use the actual table numbers to avoid ambiguity, e.g., "… in Tables 1-4".

Aegean Sea, (14) Levantine Sea 2 (central-northern part), (15) Levantine Sea 3 (central southern part), and (16) Levantine Sea 4 (eastern part).

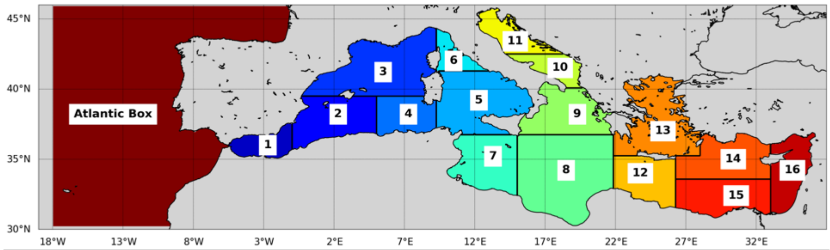

***Figure 1**. The Mediterranean Sea subdivided into sub-regions for validation metrics (see main text for region names).*

The EANs of temperature and salinity are evaluated in 9 different vertical layers: 0-10, 10-30, 30-60, 60-100, 100-150, 150-300, 300-600, 600-1000, and 1000-2000 meters to be able to quantify vertical differences in model skill and assess the model's ability to represent the vertical temperature and salinity structures.

In the following Tables (Table 1, Table 2, Table 3 and Table 4) the EANs corresponding to Mean (Observations minus Model) and RMSD for the EAS8 system are presented together with the number of available in-situ observations used for the comparison. In some cases, a lower model skill in terms of EANs can be attributed to a lower availability of measurements in specific layers/areas. E.g., in the North Adriatic area (Region 11), the number of observations were insufficient to allow reliable evaluations of SLA EANs in the chosen time period.

Temperature EANs	**EAS8 system**		
Layer [m]	**Mean [°C] (Obs-Model)**	**RMSD [°C]**	**Mean # of OBS per week**
0-10	0.06	0.56	662
10-30	0.05	0.86	1616
30-60	-0.07	0.80	1966
60-100	-0.04	0.44	2080
100-150	-0.01	0.26	1630
150-300	0.00	0.19	3342
300-600	0.00	0.15	4148
600-1000	-0.01	0.09	2695
1000-2000	-0.01	0.04	2025

***Table 1**: EANs for temperature at different vertical layers evaluated for the EAS8 system for the two-year period 2020-2021. The number of available in-situ observations in each layer is provided in the third column as the average number of observations per week.*

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SST EANs	EAS8 system		
REGION	Mean [°C] (Obs-Model)	RMSD [°C]	OBS [#]
MED SEA	0.04	0.53	46.2 M
REGION 1	-0.30	0.84	1.2 M
REGION 2	-0.06	0.49	3.1 M
REGION 3	0.03	0.58	5.0 M
REGION 4	0.00	0.46	2.0 M
REGION 5	0.08	0.47	4.3 M
REGION 6	0.10	0.45	0.9 M
REGION 7	0.14	0.47	3.1 M
REGION 8	0.09	0.54	6.9 M
REGION 9	0.07	0.52	2.8 M
REGION 10	0.14	0.57	1.2 M
REGION 11	-0.02	0.66	1.3 M
REGION 12	0.01	0.47	2.5 M
REGION 13	-0.04	0.56	3.6 M
REGION 14	0.08	0.51	3.1 M
REGION 15	0.05	0.48	3.0 M
REGION 16	0.13	0.44	2.2 M

***Table 2**: EANs for SST evaluated for the EAS8 system for the two-year period 2020-2021 for the Mediterranean Sea and 16 sub-regions (see Figure 1). The total number of available satellite observations per subregion is provided in the third column.*

Salinity EANs	EAS8 system		
Layer [m]	Mean [PSU] (Obs-Model)	RMSD [PSU]	Mean # OBS per week
0-10	-0.01	0.20	663
10-30	0.00	0.20	1616
30-60	0.00	0.17	1965
60-100	0.01	0.13	2080
100-150	0.00	0.10	1629
150-300	0.00	0.06	3341
300-600	0.00	0.03	4148
600-1000	0.00	0.02	2695
1000-2000	0.00	0.01	2024

***Table 3**: EANs for salinity at different vertical layers evaluated for the EAS8 system for the two-year period 2020-2021. The number of available in-situ observations per subregion is provided in the third column as the average number of observations per week.*

SLA EANs	EAS8 system	
REGION	RMSD [cm]	Mean # OBS per week
MED SEA	2.7	7793
REGION 1	3.5	129
REGION 2	3.1	683
REGION 3	2.6	1054
REGION 4	3.4	456
REGION 5	2.3	694
REGION 6	2.6	55
REGION 7	4.3	23
REGION 8	2.8	1457
REGION 9	2.3	600
REGION 10	2.1	61
REGION 11		
REGION 12	2.6	554
REGION 13	2.8	179
REGION 14	2.5	179
REGION 15	2.6	639
REGION 16	2.4	371

***Table 4**: EANs for SLA evaluated for the EAS8 system for the two-year period 2020-2021 for the whole Mediterranean Sea and the 16 subregions (see Figure 1). The number of available satellite observations in each subregion is provided in the third column as the average number of observations per week. For regions where there is a poor number of observations, e.g. Region 11, the result is not provided.*

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The metrics in Table 1 and Table 2 give indications about the accuracy of the MEDSEA_ANALYSISFORECAST_PHY_006_013 temperature product throughout the water column and at the surface for the entire Mediterranean Sea and the 16 subregions. Values for all vertical levels are computed using Argo profiles while SST is evaluated through comparisons with satellite observations. Temperature RMSD and MEAN values are higher in the topmost layers and decrease significantly below about 60 m. The temperature RMSD is always below 0.86°C, along the whole water column. The RMSD of the SST ranges instead from 0.51°C to 0.83°C, depending on the region considered.

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Commented [ACG23R22]: I think you misunderstood the sentence! The concept is that along the water column the RMSD is lower than 0.86 degC, while at surface, the SST RMSD ranges between 0.51 degC and 0.83 degC. However, it is clear from Table1 and Table 2.
I wrote the right sentence.

Commented [EiC24R22]: I don't think I misunderstood the sentence. The use of "SST" in combination with "along the water column" was simply wrong.

The statistics in Table 3 give indications about the accuracy of the MEDSEA_ANALYSISFORECAST_PHY_006_013 salinity field. The values for all levels are computed using Argo profiles. RMSD remains below 0.20 PSU with higher values near the surface that decrease below 150 meters.

The metrics in Table 4 define the accuracy of the MEDSEA_ANALYSISFORECAST_PHY_006_013 sea level anomaly. The statistics are computed along satellite tracks. The overall RMSD is 2.7 cm for the whole basin, ranging from 2.1 cm to 4.3 cm in individual subregions.

II PRODUCTION SYSTEM DESCRIPTION

Production centre name: Euro-Mediterranean Center on Climate Change (CMCC), Italy

Production system name: Analysis and Forecast Med-Physics EAS8 system

Copernicus Marine Product name: MEDSEA_ANALYSISFORECAST_PHY_006_013

External product: temperature (3D), salinity (3D), meridional and zonal currents (3D), vertical velocity (3D), sea surface height (2D), de-tided sea surface height (2D), de-tided sea surface zonal and meridional currents (2D), mixed layer depth (2D), seabed temperature (2D)

Frequency of model output: daily (24-h) averages, hourly (1-h) averages, monthly averages, 15-min instantaneous fields

Geographical coverage: -17.2917°W → 36.29167°E; 30.1875°N → 45.97917°N (Bay of Biscay and Black Sea are excluded)

Horizontal resolution: 1/24°

Vertical coverage: From surface to 5754 m (141 vertical, unevenly spaced levels).

Length of forecast: 10 days for the daily mean fields, 5 days for the hourly mean fields.

Frequency of forecast release: Daily.

Analyses: Yes.

Hindcast: Yes.

Frequency of analysis release: Weekly, on Tuesdays.

Frequency of hindcast release: Daily.

The analyses and physical forecast products of the Med-MFC are produced in two different cycles: a daily cycle for the production of forecasts, and a weekly cycle for the production of analyses.

The daily cycle is released each day, J, and covers the next 10 days. The forecast is initialized using daily hindcasts except on Tuesdays, when the analysis is used instead of the hindcast. Every day, the product is updated with a hindcast for day J-1 and a 10-day forecast.

The weekly cycle is released on Tuesdays and covers the previous 15 days. The assimilation cycle is daily (24h) and is conducted in filter mode. Every Tuesdays the product is updated with the analyses covering days J-15 to J-2, the hindcast for day J-1, and the 10-day forecast.

The production chain is illustrated in Figure 2.

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Commented [EC29]: Here we refer here exactly to the analysis and forecast physical product, so we would ask to go back to the initial text: "The analyses and forecasts physical product of the Med-MFC is produced".

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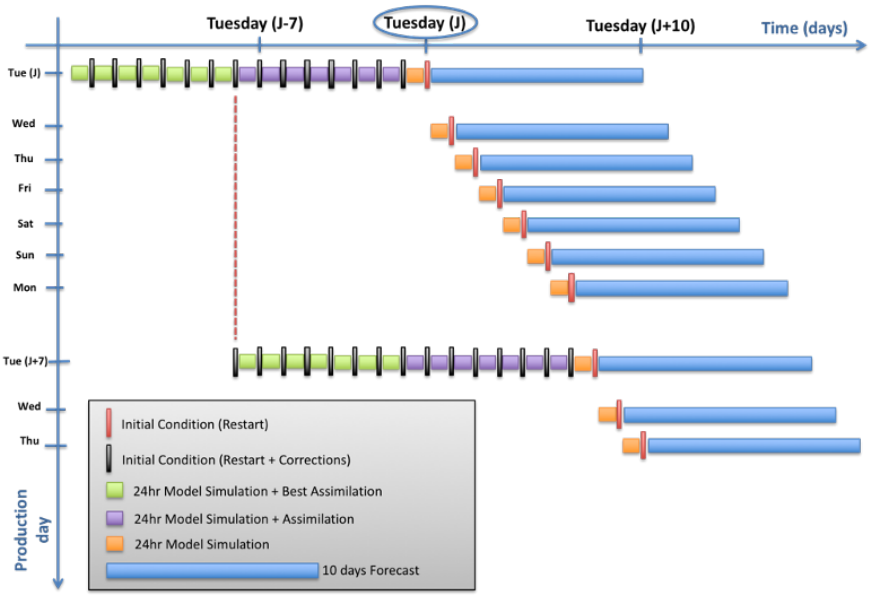

***Figure 2**: Scheme of the analysis and forecast Copernicus Marine Med-Physics processing chain.*

The Med-Physics system run is composed of several steps:

1. Upstream data acquisition, pre-processing and control of: ECMWF atmospheric forcing (numerical weather prediction), satellite (SLA and SST), and in-situ (T and S) observations.
2. Fore-/hindcast: NEMO-WW3 modelling system is run to produce a 1-day hindcast and 10-day forecast.
3. Analysis/hindcast (only on Tuesdays): NEMO-WW3 modelling system is coupled with OceanVar, a 3DVar assimilation scheme, in order to produce the best physical ocean analysis. The NEMO+WW3+OceanVar system is run for 15 days into the past in order to be able to use the best available along track SLA products. The last day of the 15-day analysis serves as the initial condition for the 10-day forecast.
4. Post processing: the model output is processed in order to obtain the products for the Copernicus Marine Service catalogue.
5. Output delivery.

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Commented [EC38R37]: Yes, it is correct

II.1 Description of the Med-Physics EAS8 model system

Since the year 2000, the Mediterranean Forecasting System, MedFS, (Pinardi et al., 2003, Pinardi and Coppini 2010, Tonani et al., 2014) has been providing analyses and short-term forecasts of the main physical parameters for the Mediterranean Sea. It is the physical component of the Med-MFC and is called Med-Physics.

The Copernicus Marine Med-Physics analysis and forecast system EAS8 employs a coupled hydrodynamic-wave model implemented over the whole Mediterranean basin and extended into the Atlantic Sea in order to better resolve exchanges with the Atlantic Ocean at the Strait of Gibraltar. The model horizontal grid resolution is 1/24˚ (ca. 4 km) with 141 unevenly spaced vertical levels.

The hydrodynamics are supplied by the Nucleus for European Modelling of the Ocean (NEMO v4.2) while the wave component is provided by WaveWatch-III (WW3, v6.07). The model solution is updated by OceanVar (an ocean 3DVar scheme) assimilating temperature and salinity vertical profiles and along track satellite sea level anomaly observations.

Circulation model component (NEMO)

The oceanic equations of motion of Med-Physics system are solved by an Ocean General Circulation Model (OGCM) based on NEMO version 4.2 (Madec et al., 2023). The code is developed and maintained by the NEMO-consortium.

NEMO has been implemented in the Mediterranean at 1/24° x 1/24° horizontal resolution and 141 unevenly spaced vertical levels (Clementi et al., 2017a) with time step of 180 s. The model covers the whole Mediterranean Sea and also extends into the Atlantic in order to better resolve the exchanges with the Atlantic Ocean at the Strait of Gibraltar.

The NEMO code solves the primitive equations using the time-splitting technique that is the external gravity waves are explicitly resolved with non-linear free surface formulation and time-varying vertical z-star coordinates.

The advection scheme for active tracers, temperature and salinity, is a mixed up-stream/MUSCL (Monotonic Upwind Scheme for Conservation Laws; Van Leer, 1979), originally implemented by Estubier and Lévy (2000) and modified by Oddo et al. (2009). The vertical diffusion and viscosity terms are a function of the Richardson number as parameterized by Pacanowsky and Philander (1981).

The model interactively computes air-surface fluxes of momentum, mass, and heat. The bulk formulae implemented are described in Pettenuzzo et al. (2010) and are currently used in the Mediterranean operational system (Tonani et al., 2015). A detailed description of other specific features of the model implementation can be found in Oddo et al., (2009, 2014).

The vertical background viscosity and diffusivity values are set to 1.2e-6 [m^2/s] and 1.0e-7 [m^2/s], respectively, while the horizontal bilaplacian eddy diffusivity and viscosity are respectively set equal to -1.2e8 [m^4/s] and -2.0e8 [m^4/s]. A quadratic bottom drag coefficient with a logarithmic formulation has been used according to Maraldi et al. (2013) and the model uses vertical partial cells to fit the bottom depth shape.

Tidal waves have been included since the EAS6 system version, so that the tidal potential is computed across the domain for the 8 major constituents found in the Mediterranean Sea: M2, S2, N2, K2, K1, O1, P1, Q1. In addition, tidal forcing is applied along the lateral boundaries in the Atlantic Ocean by means of tidal elevation estimated using FES2014 (Carrere et al., 2016) tidal model and tidal currents evaluated using TUGO (Toulouse Unstructured Grid Ocean model, ex-Mog2D; Lynch and Gray, 1979).

In the Atlantic, the hydrodynamic model is nested within the Global analysis and forecast system GLO-MFC daily data set (1/12° horizontal resolution, 50 vertical levels) that is interpolated onto the Med-

Currents model grid. Details on the nesting technique and major impacts on the model results are in Oddo et al. (2009).

The model is forced by momentum, water and heat fluxes interactively computed by bulk formulae using the 1/10° horizontal-resolution operational analysis and forecast fields from the European Centre for Medium-Range Weather Forecasts (ECMWF) at highest available time frequency (1 hour for the first 3 days of forecast, 3 hours for the following 3 days of forecast and 6 hours for the last 4 days of forecast and for the analysis) and the model sea surface temperature (details of the air-sea physics are in Tonani et al., 2008). The water balance is computed as Evaporation minus Precipitation and Runoff. The evaporation is derived from the latent heat flux, precipitation is provided by ECMWF as daily averages, while the runoff of the 39 rivers implemented is provided by:

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- daily mean observed discharge for the Po river distributed by ARPAE (Regional Agency for Prevention, Environment and Energy of Emilia-Romagna, Italy) and available from the website: https://simc.arpae.it/dext3r/. The Po river discharge is measured at the closing point of the drainage basin in Pontelagoscuro.
- monthly mean datasets for the remaining 38 rivers: the Global Runoff Data Centre dataset (Fekete et al., 1999) for the Ebro, Nile and Rhone rivers; the dataset from Raicich (1996) for: Vjosë, Seman rivers; the UNEP-MAP dataset (Implications of Climate Change for the Albanian Coast, Mediterranean Action Plan, MAP Technical Reports Series No.98., 1996) for the Buna/Bojana river; the PERSEUS dataset for the following 32 rivers: Piave, Tagliamento, Soca/Isonzo, Livenza, Brenta-Bacchiglione, Adige, Lika, Reno, Krka, Arno, Nerveta, Aude, Trebisjnica, Tevere/Tiber, Mati, Volturno, Shkumbini, Struma/Strymonas, Meric/Evros/Maritsa, Axios/Vadar, Arachtos, Pinios, Acheloos, Gediz, Buyuk Menderes, Kopru, Manavgat, Seyhan, Ceyhan, Gosku, Medjerda, Asi/Orontes.

Objective Analyses-Sea Surface Temperature (OA-SST) fields from CNR-ISA SST-TAC are used for the correction of surface heat fluxes with the relaxation constant of 110 $Wm^{-2}K^{-1}$ centred at midnight since the observed dataset corresponds to the foundation SST (~SST at midnight).

The Dardanelles Strait is implemented as a lateral open boundary condition by using GLO-MFC daily Analysis and Forecast product and daily climatology derived from a Marmara Sea box model (Maderich et al., 2015).

The topography is created starting from the GEBCO 30arc-second grid (http://www.gebco.net/data_and_products/gridded_bathymetry_data/gebco_30_second_grid/), filtered (using a Shapiro filter) and manually modified in critical areas such as near the islands along the Eastern Adriatic coast, near the Gibraltar and Messina straits, and at the Atlantic box edge.

Wave model component (WW3)

The wave dynamics are solved by a Mediterranean implementation of the WaveWatch-III (WW3) code version 6.07 (WaveWatch III Development Group, 2019). WW3 covers the same domain and follows the same horizontal discretization of the circulation model (1/24° x 1/24°) with a time step of 180 sec. The wave model uses 24 directional bins (15° directional resolution) and 30 frequency bins (ranging between 0.05 Hz and 0.7931 Hz) to represent the wave spectral distribution.

WW3 has been forced by the same 1/10° horizontal resolution ECMWF atmospheric forcing that is used to force the hydrodynamic model. Wind speed is modified by considering a stability parameter that depends on the air-sea temperature difference (cf., Tolman, 2002).

The wave model takes into consideration the surface currents for wave refraction but assumes no interactions with the ocean bottom. The WW3 model solves the wave action balance equation that describes the evolution, in slowly varying bathymetries and currents, of a 2D ocean wave spectrum where individual spectral components locally satisfy linear wave theory. In the present application, WW3 has been implemented following WAM cycle4 model physics (Gunther et al., 1993). Wind input and dissipation terms are based on Janssen's quasi-linear theory of wind-wave generation (Janssen, 1989, 1991). The dissipation term is based on Hasselmann's (1974) whitecapping theory using the implementation by Komen et al. (1984). Non-linear wave-wave interactions are modelled using the Discrete Interaction Approximation (DIA, Hasselmann et al., 1985).

Commented [EiC40]: ? Do you mean "bathymetries"?

Commented [EC41R40]: yes

Commented [EiC42R40]:

Commented [EiC43]: Best guess, please check.

Commented [EC44R43]: Yes, it is fine

Commented [EiC45]: Best guess. OK?

Commented [EC46R45]: Yes, it is fine

Model coupling (NEMO-WW3)

The coupling between the hydrodynamic model (NEMO) and the wave model (WW3) is achieved by an online hourly two-way coupling and consists in exchanging the following fields: NEMO sends to WW3 the air-sea temperature difference and the surface currents, while WW3 sends to NEMO the neutral drag coefficient used to evaluate the surface wind stress.

More details on the model coupling and on the impact of the coupled system on both wave and circulation fields can be found in Clementi et al. (2017b).

Data assimilation scheme (OceanVar)

The data assimilation system is based on a 3D variational ocean data assimilation scheme, OceanVar, developed by Dobricic and Pinardi (2008) and later upgraded by Storto et al. (2016). The background error covariance matrices vary monthly at each grid point in the discretized domain of the Mediterranean Sea. EOFs have been calculated from the 30-year Mediterranean Reanalysis product (MEDSEA_MULTIYEAR_PHY_006_004). Assimilated observations are: along-track SLA (a satellite product including dynamical atmospheric correction and ocean tides is chosen, as specified in II.3) from SEALEVEL-TAC and in-situ vertical temperature and salinity profiles from VOS XBTs (Voluntary Observing Ship-eXpandable Bathythermograph) and ARGO floats. In-situ observational errors are estimated iteratively as described in Desroziers et al. (2005). Altimetry observational errors are assumed to be 3 cm and the same for all satellites. Deviations from observations (innovations) are computed with the First Guess at Appropriate Time (FGAT) technique. In the Mediterranean, both altimeter and in-situ data are assimilated, while in the Atlantic box only in-situ data is assimilated.

Commented [EiC47]: Suggest "deviations". Please check.

Commented [EiC48]: ? Not sure what you mean here. E.g., animals can "ingest" food, or people can (metaphorically) "ingest" knowledge, but in this context this makes no sense. If you mean "assimilated" please use this term. In scientific writing, accuracy should never be sacrificed for style (i.e., do not add ambiguity simply to avoid repeating the same term). Edit is best guess. Please check.

II.2 New features of the Med-Physics EAS8 system

The main differences between the Copernicus Marine Med-Physics EAS7 and EAS8 systems are described below and summarized in Table 5.

	Copernicus Marine Med-Physics EAS8
Upgrades in the modelling system	Updated NEMO version from NEMO 3.6 to NEMO 4.2 Updated WW3 version form 3.14 to 6.07 Increased the time step from 120 to 180 seconds Removed the Topographic Wave Drag parameterization that describes the momentum dissipation by tides over rough topography below 500 m depth Improved air-sea bulk formulae with updated parameter values
Changes in Data Assimilation	Included assimilation of in-situ data in the Atlantic box New EOFs
New variables in catalogue	Daily mean de-tided sea surface height and surface currents

***Table 5**: Differences between the current (EAS8) and previous (EAS7) Med-Physics systems.*

Commented [EiC49]: Did you replace it with anything or simply remove it? How does the model now account for this momentum dissipation?

Commented [ACG50R49]: Just removed. We are not accounting for this effect in the current version.

Commented [EiC51R49]: OK

Commented [EiC52]: Is this SSH or SLA? Please use correct term to avoid ambiguity.

Commented [ACG53R52]: Done

II.3 Upstream data and boundary condition of the NEMO-WW3-OceanVar system

The Copernicus Marine MED-Physics system uses the following upstream data:

1. Atmospheric forcing (including precipitation): NWP 6-h (1-h for the first 3 days of forecast, 3-h for the following 3 days of forecast), 0.10° horizontal-resolution operational analysis and forecast fields from the European Centre for Medium-Range Weather Forecasts (ECMWF) distributed by the Italian National Meteorological Service (USAM/CNMA)
2. Runoff: ARPAE (Regional Agency for Prevention, Environment and Energy of Emilia-Romagna, Italy, https://simc.arpae.it/dext3r/) daily measurements for the Po River; monthly climatologies derived from: Global Runoff Data Centre dataset (Fekete et al., 1999) for Ebro, Nile and Rhone rivers, the dataset from Raicich (1996) for the Adriatic rivers Vjosë and Seman, the UNEP-MAP dataset (Implications of Climate Change for the Albanian Coast, Mediterranean Action Plan, MAP Technical Reports Series No.98., 1996) for the Buna/Bojana rivers, and the PERSEUS project dataset for the other 32 rivers.
3. Initial conditions for temperature and salinity on 01/01/2015 are based on winter climatological fields from WOA13 V2 (World Ocean Atlas 2013 V2, https://www.nodc.noaa.gov/OC5/woa13/woa13data.html)
4. Lateral boundary conditions from Copernicus Marine Global Analysis and Forecast system: GLOBAL_ANALYSISFORECAST_PHY_001_024 (1/12° horizontal resolution, 50 vertical levels).
5. Lateral boundary tidal signal: tidal elevation data from FES2014 (Carrere et al., 2016) and tidal currents from TUGO (Toulouse Unstructured Grid Ocean model, ex-Mog2D; Lynch and Gray, 1979).

6. Data assimilation:
    - Temperature and salinity vertical profiles from Copernicus Marine INSITU TAC product:
        - INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030
    - Satellite along-track SLA from Copernicus Marine SL TAC products:
        - SEALEVEL_EUR_PHY_L3_REP_OBSERVATIONS_008_061 (until Dec 2021)
        - SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059 (from Jan 2022 to present)
    - Satellite SST from Copernicus Marine SST TAC product (nudging):
        - SST_MED_SST_L4_NRT_OBSERVATIONS_010_004

III VALIDATION FRAMEWORK

In order to evaluate and ensure the quality of the MEDSEA_ANALYSISFORECAST_PHY_006_013 product, an assimilation experiment was performed using the system described in Section II, which is operational since November 2023, and covers 8 years from January 2015 to December 2022 (January to December 2015 serves as spin-up period and runs without data assimilation).

The qualification task has been carried out for the two-year period from January 2020 to December 2021, based on Class 1, Class 2, and Class 4 diagnostics.

The performance of the new Med-Physics EAS8 system has been assessed using external products, namely quasi-independent satellite and in-situ observations for temperature, salinity and SLA, independent fixed mooring and HF radar observations for coastal currents, independent tide gauge data for harmonic analyses, and climatological datasets to assess the quality of bottom temperature and MLD.

All quasi-independent data (satellite SLA and SST and in situ vertical profiles of temperature and salinity from XBT and Argo) are assimilated into the system. Diagnostics in terms of RMSD and/or biases are computed using the model fields prior to data assimilation and applying the increments.

The observational datasets used for the qualification task are listed in Table 6.

QUASI-INDEPENDENT DATA	
TYPE	**COPERNICUS MARINE PRODUCT NAME**
ARGO, XBT	INSITU_GLO_PHYBGCWAV_DISCRETE_MYNRT_013_030
SLA	SEALEVEL_EUR_PHY_L3_REP_OBSERVATIONS_008_061 SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059
SST	SST_MED_SST_L4_NRT_OBSERVATIONS_010_004
INDEPENDENT DATA	
TYPE	**PRODUCT NAME**
MOORINGS, HF-radars Tide gauges	INSITU_MED_NRT_OBSERVATIONS_013_035 EMODnet Physics

***Table 6**: List of quasi-independent and independent observations used for the model-data comparison.*

In this section, we present the validation results for temperature (including bottom T and SST), salinity, SLA, SSH, currents (also in terms of transport through straits), and MLD (see Table 8 for a summary).

Commented [EiC54]: ? "ensure"?

Commented [ACG55R54]: Done

Commented [EiC56]: Once this QUID is published it will be operational.

Commented [ACG57R56]: In fact, once the QUID will be available to the users, the system will be operational. In my opinion "is" (present) is correct.

Commented [EiC58R56]: Yes but you had future tense "is going to be". It is correct now that I have corrected it. I am starting to think you maybe looked at this document in "Simple Markup" mode and cannot see your original text.

Commented [EiC59]: Please briefly define classes.

Commented [ACG60R59]: The technical description of the classes used in the QUID can be found in the Scientific Qualification Plan (ScQP) document. We are required to refer to this in the QUID by Mercator. So, since there is a dedicated document, I don't think we should repeat the definitions in the QUID.

Commented [EiC61]: ? Unable to understand. Needs clarifying.

Commented [ACG62R61]: This are the basics of Data assimilation theory. In my opinion, explaining how it works would require too many lines, and is out of the scope of the QUID document…

Metric Name	Description	Ocean parameter	Supporting reference dataset	Quantity
NRT evaluation of Med-MFC-Physics using semi-independent data: Estimate Accuracy Numbers. Daily mean model outputs compared to observations.				
T-<X-Y>m-D-CLASS4-PROF-RMSD-Jan2020-Dec2021	Temperature vertical profiles comparison with respect to Copernicus Marine INSITU TAC data at several layers for the Mediterranean basin.	Temperature	Argo floats, XBTs from the Copernicus Marine INSITU TAC product: INSITU_MED_NRT_OBSERVATIONS_013_035	Time series of Temperature daily RMSD of the difference between in-situ observations and system outputs averaged over the qualification testing period (Jan 2020-Dec 2021). This quantity is evaluated on the model analysis. The statistics are defined for all the Mediterranean Sea and are evaluated for several layers. Together with the time series, the time (2020-2021) average RMSD value is reported in tables.
T-<X-Y>m-D-CLASS4-PROF-BIAS-Jan2020-Dec2021	Temperature vertical profiles comparison with respect to Copernicus Marine INSITU TAC data at several layers for the Mediterranean basin.	Temperature	Argo floats, XBTs from the Copernicus Marine INSITU TAC product: INSITU_MED_NRT_OBSERVATIONS_013_035	Time series of Temperature daily mean differences between in-situ observations and system outputs averaged over the qualification testing period (Jan 2020-Dec 2021). This quantity is evaluated on the model analysis. The statistics are defined for all the Mediterranean Sea and are evaluated for several different layers. Together with the time series, the time (2020-2021) averaged BIAS value is reported in tables.
S-<X-Y>m-D-CLASS4-PROF-RMSD-Jan2020-Dec2021	Salinity vertical profiles comparison with respect to Copernicus Marine INSITU TAC data at several layers for the Mediterranean basin.	Salinity	Argo floats, XBTs from the Copernicus Marine INSITU TAC product: INSITU_MED_NRT_OBSERVATIONS_013_035	Time series of Salinity daily RMSs of the difference between in-situ observations and system outputs averaged over the qualification testing period (Jan 2020-Dec 2021). This quantity is evaluated on the model analysis. The statistics are defined for all the Mediterranean Sea and are evaluated for several different layers. Together with the time series, the time (22020-2021) averaged RMSD value is reported in tables.
S-<X-Y>m-D-CLASS4-PROF-BIAS-Jan2020-Dec2021	Salinity vertical profiles comparison with Copernicus Marine INSITU TAC data at several layers for the Mediterranean basin.	Salinity	Argo floats, XBTs from the Copernicus Marine INSITU TAC product: INSITU_MED_NRT_OBSERVATIONS_013_035	Time series of Salinity daily mean differences between in-situ observations and system outputs averaged over the qualification testing period (Jan 2020-Dec 2021). This quantity is evaluated on the model analysis. The statistics are defined for all the Mediterranean Sea and are evaluated for several layers. Together with the time series, the time (2020-2021) averaged BIAS value is reported in tables.

Table 7: List of metrics for Med-Physics evaluation using in-situ and satellite observations (continues on next pages).

Commented [EiC63]: Name of what? Is this the name in the datasets published in the CMEMS catalogue? If so, consider using "Dataset name" or something to this effect.

Commented [ACG64R63]: Each raw of the table correspond to a METRIC, as described in the Table caption.
The technical description of the metrics used in the QUID (bias and RMSD) can be found in the Scientific Qualification Plan (ScQP) document. We are required to use this metrics in the QUID by Mercator and refer to them using their names, defined in the ScQP.

Commented [EiC65R63]: OK so I have added "Metric" to "Name" to be more specific.

Metric Name	Description	Ocean parameter	Supporting reference dataset	Quantity
NRT evaluation of Med-MFC-Physics using semi-independent data: Estimate Accuracy Numbers. Daily mean model outputs compared to observations.				
SST-SURF-D-CLASS4-RAD-RMSD-Jan2020-Dec2021	Sea Surface Temperature comparison with respect to SST Copernicus Marine SST TAC L4 (satellite) data for the Mediterranean basin and selected sub-basins.	Sea Surface Temperature	SST satellite data from Copernicus Marine SST TAC L4 product: SST_MED_SST_L4_NRT_OBSERVATIONS_010_004	Time series of Sea surface temperature daily RMSs of the difference between satellite observations and system outputs averaged over the qualification testing period (Jan 2020-Dec 2021). This quantity is evaluated on the model analysis. The statistics are defined for all the Mediterranean Sea, 16 selected sub-basins and the Atlantic box. Together with the time series, the time (2020-2021) average RMSD value is reported in tables.
SST-SURF-D-CLASS4-RAD-BIAS-Jan2020-Dec2021	Sea Surface Temperature comparison with respect to SST Copernicus Marine SST TAC L4 (satellite) data for the Mediterranean basin and selected sub-basins.	Sea Surface Temperature	SST satellite data from Copernicus Marine SST TAC L4 product: SST_MED_SST_L4_NRT_OBSERVATIONS_010_004	Time series of Sea surface temperature daily mean differences between satellite observations and system outputs averaged over the qualification testing period (Jan 2020-Dec 2021). This quantity is evaluated on the model analysis. The statistics are defined for all the Mediterranean Sea, 16 selected sub-basins basins and the Atlantic box. Together with the time series, the time (2020-2021) average BIAS value is reported in tables.
NRT evaluation of Med-MFC-Physics using semi-independent data. Weekly comparison of Estimate Accuracy Numbers. Daily mean model outputs compared to observations.				
T-<X-Y>m-W-CLASS4-ASSIM–PROF-RMSD-MED-Jan2020-Dec2021	Temperature vertical profiles comparison with Copernicus Marine INSITU TAC data at 5 specified depths.	Temperature	Argo floats, CTD and XBT from the Copernicus INSITU TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	Time series of weekly RMSs of temperature EANs. Together with the time series, the average value of weekly RMSD is evaluated over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea and are evaluated at five different depths: 8, 30, 150, 300 and 600 m.
S-<X-Y>m-W-CLASS4–ASSIM-PROF-RMSD-MED-Jan2020-Dec2021	Salinity vertical profiles comparison with Copernicus Marine INSITU TAC data at 5 specified depths.	Salinity	Argo floats from the Copernicus Marine INSITU TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	Time series of weekly RMSs of salinity EANs. Together with the time series, the average value of weekly RMSD is evaluated over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea and are evaluated at five different depths: 8, 30, 150, 300 and 600 m.
SLA-SURF-2W-CLASS4-ASSIM-ALT-RMSD-MED-Jan2020-Dec2021	Sea level anomaly comparison with Copernicus Marine Sea Level TAC satellite along track data for the Mediterranean basin.	Sea Level Anomaly	Satellites (Jason3, CryoSat-2, Altika, Sentinel 3A/3B, HY-2A/2B) Sea Level along track data from Copernicus Marine Sea Level TAC product: SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_061 SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059	Time series of weekly RMSs of sea level anomaly EANs. Together with the time series, the average value of weekly RMSD is evaluated over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea and are evaluated for the different assimilated satellites.

***Table 7 (continued)**: List of metrics for Med-Physics evaluation using in-situ and satellite observations.*

Metric Name	Description	Ocean parameter	Supporting reference dataset	Quantity
NRT evaluation of Med-MFC-Physics using semi-independent data. Depth-Time Weekly comparison of Estimate Accuracy Numbers (Hovmoller diagrams). Daily mean model outputs compared to observations.				
T-<X-Y>m-W-CLASS4–PROF-RMSD-MED-Jan2020-Dec2021-HOV	Temperature depth-time comparison with Copernicus Marine INSITU TAC between 0 and 900m.	Temperature	Argo floats, CTD and XBT from the Copernicus Marine INSITU TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	Depth-Time (Hovmoller diagram) of two-weekly RMS temperature EANs evaluated over the qualification testing period (2020-2021). The statistics are averaged over the whole Mediterranean Sea and are defined between 0 and 900m depth.
S-<X-Y>m-W-CLASS4–PROF-RMSD-MED-Jan2020-Dec2021-HOV	Salinity depth-time comparison with Copernicus Marine INSITU TAC between 0 and 900m.	Salinity	Argo floats, CTD and XBT from the Copernicus Marine INSITU TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	Depth-Time (Hovmoller diagram) of monthly RMS salinity EANs evaluated over the qualification testing period (2020-2021). The statistics are averaged over the whole Mediterranean Sea and are defined between 0 and 900m depth.
NRT evaluation of Med-MFC-Physics using semi-independent data. 2D MAPS of Yearly comparison of Estimate Accuracy Numbers. Daily mean model outputs compared to observations.				
T-<X-Y>m-2Y-CLASS4–PROF-RMSD-TS-Jan2020-Dec2021-2DMAP	Temperature comparison with respect to Copernicus Marine INSITU TAC data at several layers for the Mediterranean basin.	Temperature	Argo floats and XBT from the Copernicus Marine INSITU TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	2D MAPS of RMSD of temperature (EANs) averaged over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea and are evaluated in several vertical layers: 0-10, 10-30, 30-60, 60-100, 100-150, 150-300, 300-600, 600-1000, 1000-2000 meters. The statistics are evaluated on single seasons: winter, spring, summer and fall
S-<X-Y>m-2Y-CLASS4–PROF-RMSD-TS-Jan2020-Dec2021-2DMAP	Salinity comparison with respect to Copernicus Marine INSITU TAC data at several layers for the Mediterranean basin.	Salinity	Argo floats from the Copernicus Marine INSITU TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	2D MAPS of RMSD of salinity (EANs) averaged over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea and are evaluated in several vertical layers: 0-10, 10-30, 30-60, 60-100, 100-150, 150-300, 300-600, 600-1000, 1000-2000 meters. The statistics are evaluated on single seasons: winter, spring, summer and fall
SLA-SURF-2Y-CLASS4–ALT-RMSD-TS-Jan2020-Dec2021-2DMAP	Sea Level Anomaly comparison with respect to Copernicus Marine INSITU TAC.	Sea Level	Satellites (CryoSat-2, Altika, Sentinel 3A and Sentinel 3B, HY-2B) Sea Level along track data: SEALEVEL_EUR_PHY_L3_REP_OBSERVATIONS_008_061 SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059	2D MAPS of RMSD of Sea Level Anomaly (EANs) averaged over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea. The statistics are evaluated on single seasons: winter, spring, summer and fall
SLA-SURF-2Y-CLASS4–ALT-BIAS-TS-Jan2020-Dec2021-2DMAP	Sea Level Anomaly comparison with respect to Copernicus Marine INSITU TAC.	Sea Level	Satellites (CryoSat-2, Altika, Sentinel 3A and Sentinel 3B, HY-2B) Sea Level along track data: SEALEVEL_EUR_PHY_L3_REP_OBSERVATIONS_008_061 SEALEVEL_EUR_PHY_L3_NRT_OBSERVATIONS_008_059	2D MAPS of bias of Sea Level Anomaly (EANs) averaged over the qualification testing period (2020-2021). The statistics are defined for all the Mediterranean Sea The statistics are evaluated on single seasons: winter, spring, summer and fall

***Table 7 (continued)**: List of metrics for Med-Physics evaluation using in-situ and satellite observations.*

Metric Name	Description	Ocean parameter	Supporting reference dataset	Quantity
NRT evaluation of Med-MFC-Physics using independent data. Daily comparison with tide-gauges, moorings and HF radars.				
UV-SURF-D-CLASS2-MOOR-RMSD-Jan2020-Dec2021	Surface currents comparison with Copernicus Marine INSITU TAC fixed moorings and HF radars	Currents	Moored buoys and HF Radars from Copernicus Marine InSitu TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	RMSD of model daily mean outputs with respect to *in-situ* fixed moorings and HF radar observations for the surface layer (0-3 m) averaged in the selected qualification period. The mean values (averaged in the whole basin and in the entire validation period) are presented in a dedicated table.
UV-SURF-D-CLASS2-MOOR-BIAS-Jan2020-Dec2021	Surface currents comparison with Copernicus Marine INSITU TAC fixed moorings and HF radars	Currents	Moored buoys and HF radars from Copernicus Marine InSitu TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	Bias of model daily mean outputs with respect to *in-situ* fixed moorings and HF radar observations for the surface layer (0-3 m) averaged in the selected qualification period. The mean values (averaged in the whole basin and in the entire validation period) are presented in a dedicated table.
UV-SURF-D-CLASS2-MOOR-mean-SC	Surface currents comparison with Copernicus Marine INSITU TAC fixed moorings and HF radars	Currents	Moored buoys and HF radars from Copernicus Marine InSitu TAC products: INSITU_MED_NRT_OBSERVATIONS_013_035	Scatter plot of model daily mean outputs with respect to *in-situ* fixed moorings and HF radar observations for the surface layer (0-3 m).
SL-SURF-D-CLASS2-TG-MEAN-SC	Harmonic analysis: Tidal sea level amplitude and phase comparison with tide gauges	Tidal sea level	Tide-gauges from EMODnet dataset	Scatter plot of model tidal sea level amplitude and phase compared to tide gauges observations. The plots are presented for the 4 major Mediterranean Sea tidal constituents (M2, S2, K1, O1)
SL-SURF-D-CLASS2-TG-RMS-VAL	Harmonic analysis: Tidal sea level amplitude and phase comparison with tide gauges	Tidal sea level	Tide-gauges from EMODnet dataset	Mean RMS of the vectorial distance between model outputs and tide gauges measurements. These metrics are presented in a dedicated table for all the 8 tidal constituents represented by the model.
SL-SURF-D-CLASS2-LIT-VECD-VAL	Harmonic analysis: Tidal sea level amplitude and phase comparison with tide gauges in terms of vectorial distance	Tidal sea level	Reference values from literature (Tsimplis et al. 1995, Palma et al. 2020)	Mean vectorial distance between model outputs and reference literature values using a sub-set of tide gauges (#35) which were used in previous literature evaluations (Tsimplis et al. 1995, Palma et al. 2020) These metrics are presented in a dedicated table for the 4 major Mediterranean Sea tidal constituents (M2, S2, K1, O1) and compared to refence values.
SL-SURF-D-CLASS2-TPXO-RMS-VAL	Harmonic analysis: Tidal sea level amplitude and phase comparison with TPXO9 global model in terms of vectorial distance	Tidal sea level	Reference values from TPXO9 Global Barotropic Model (Egbert et al., 2002)	Mean vectorial distance between model outputs and TPXO9 model outputs (Egbert et al., 2002) These metrics are presented in a dedicated table for ALL the 8 Mediterranean Sea tidal constituents and are the result of the computation on the whole EAS model grid.
SL-SURF-D-CLASS4-TPXO-AMP-2DMAP	Harmonic analysis: Tidal sea level amplitude and phase comparison with TPXO9 global model in terms of tidal Amplitude	Tidal sea level	Reference values from TPXO9 Global Barotropic Model (Egbert et al., 2002)	2D Map of amplitude differences between model outputs and TPXO9 model outputs (Egbert et al., 2002)

***Table 7 (continued)**: List of metrics for Med-Physics evaluation using in-situ and satellite observations.*

Metric Name	Description	Ocean parameter	Supporting reference dataset	Quantity
NRT evaluation of Med-MFC-Physics using Climatological dataset				
MLD-D-CLASS1-CLIM-MEAN_M-MED	Mixed Layer Depth comparison with climatology from literature in the Mediterranean Sea	Mixed Layer Depth	Monthly climatology from literature (Houpert et al., 2015)	Comparison of climatological maps form model outputs computed over the two-years period 2020-2021 and a climatological dataset (Houpert at al., 2015)
SBT-D-CLASS4-CLIM-MEAN_M-MED	Bottom Temperature comparison with a climatological dataset in the Mediterranean Sea	Sea Bottom Temperature	SeaDataNet climatological datasets	Time series of mean (computed over the two-years period 2020-2021) monthly mean Sea Bottom Temperature from model outputs and SeaDataNetEAS4 climatologies. The time series are presented for the entire basin, for the area with topography < 500m and for the areas with topography < 1500m
SBT-D-CLASS1-CLIM-MEAN_M-MED	Bottom Temperature comparison with a climatological dataset in the Mediterranean Sea	Sea Bottom Temperature	SeaDataNet climatological datasets	Comparison of climatological maps form model outputs computed over the two-years period 2020-2021 and SeaDataNet climatologies for the area with topography < 1500m
NRT evaluation of Med-MFC-Physics integrated quantities against previous estimates in literature				
TRANSP-D-CLASS3-LIT-MEAN-GB-VAL	Mean volume transport (net, east- and west-ward) at Gibraltar strait with respect to literature.	Volume transport at Gibraltar Strait	Literature fluxes (Soto-Navaro et al., 2010).	Comparison of the mean volume transport (net, east- and west-ward) at Gibraltar strait with respect to literature fluxes (Soto-Navaro et al., 2010). The metric is presented as an average value in the qualification period.

***Table 7 (continued)**: List of metrics for Med-Physics evaluation using in-situ and satellite observations.*

IV VALIDATION RESULTS

IV.1 Temperature

RMSD and bias for temperature were calculated based on a comparison between the weekly analysis of the MEDSEA_ANALYSISFORECAST_PHY_006_013 product and quasi-independent data (**Table 8**). SST accuracy is measured through EANs estimation with respect to the satellite values used for the relaxation of surface heat fluxes. The validation is based on the two-year period 2020-2021 and results for temperature at depth are provided at 5 depths (8, 30, 150, 300, and 600 m) showing that RMSD is maximal at 30 m and decreases for increasing depths.

Variables/estimated accuracy:	Metrics		Depth [m]	Observation
SEA SURFACE TEMPERATURE	RMSD [°C]	BIAS [°C]		
	0.53	0.04	0	Satellite SST
TEMPERATURE	0.58	0.08	8	Argo
	0.91	-0.04	30	Argo
	0.22	-0.01	150	Argo
	0.17	0.00	300	Argo
	0.13	0.03	600	Argo

Table 8: ENAs based on comparisons with quasi-independent data for two-year period 2020-2021.

Temperature RMSD is generally higher at depths between 10 and 60 meters and model skill improves below 150 m (Figure 3). Regarding seasonal variability, the topmost layers have higher RMSD during the warm summer and autumn seasons, especially in the thermocline between 30-60 m (Figure 3 and Figure **4**).

Maps of basin-averaged statistics confirm that the largest discrepancies occur at depths between 10-60 m, especially during the autumn season (Figure 5).

Commented [EiC66]: This should probably be Table 8.

Commented [ACG67R66]: Done

Commented [EiC68]: "Means of EANs computation" is grammatically incorrect and as a sentence incomprehensible. This needs to be rewritten for clarity/comprehension. Unclear what you are averaging.

Commented [ACG69R68]: The original sentence was "two-weekly mean" meaning "two-weekly-average"! I wrote the correct sentence without going in too much detailed description.

Commented [EiC70]: What synthesis? Do you mean the "validation"? Unclear.

Commented [ACG71R70]: Done

Commented [EiC72]: Presumably now you are no longer talking about SST since you are providing depths. Please rewrite this entire paragraph for improved clarity/comprehension.

Commented [ACG73R72]: As the title of the Paragraph states, here we should provide the validation results for temperature. This field is defined at several depth (it is a 3D field), the values at the surface are called Sea Surface Temperature field (SST). Therefore, we provide the validation at several depth and at the surface

Commented [EiC74R72]: If this is the case, then why did your previous sentence start with "The accuracy of SST …"?

Commented [EiC75]: You table does not contain the term "error". Hence it is unclear what you are referring to. Please use the terms shown in the table, i.e. RMSD and BIAS.

Commented [EiC76]: "Errors" do not have skills.

Commented [EiC77R76]:

Commented [EiC78]: Where is this result shown? Presumably in Figure 4? My edit assumes this. Please check.

Commented [ACG79R78]: Both Fig. 3 and Fig. 4 (as was written in the original text)

Commented [EiC80R78]: ? You seem to be mistaking my edits for "original text". The original version of this sentence did not contain any figure references. I added Figure 4 and you added Figure 3 on 27 October.

Commented [EiC81]: You also need to reference the corresponding figure here. Assuming Figure 5, please check.

Commented [ACG82R81]: Yes (as was written in the original text)

Commented [EiC83R81]: ? I really do not understand your comments. The original text had "Error! Reference source not found." So there was no mention of Figure 5.

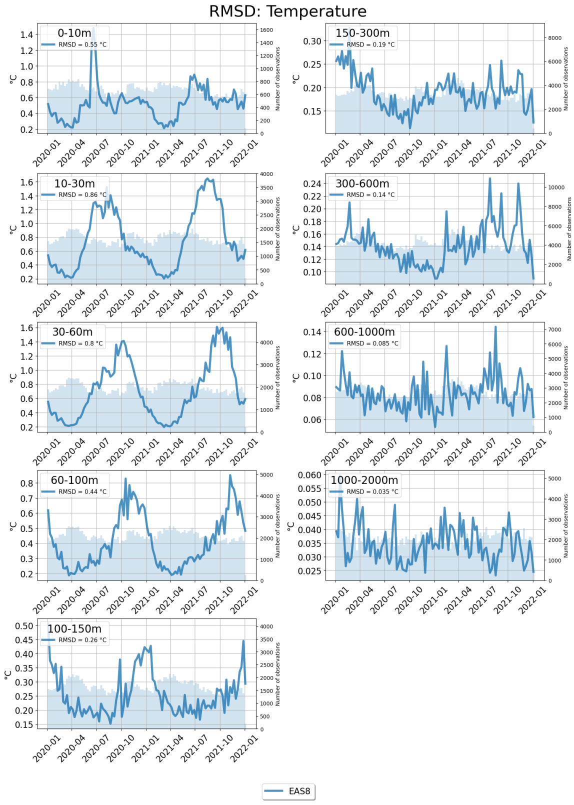

Figure 3*: Time series of weekly RMSD for temperature (solid lines) in various layers. Shaded areas indicate the number of available observations for the RMSD calculation (T-<X-Y>m-W-CLASS4- ASSIM–PROF-RMSD-MED-Jan2020-Dec2021).*

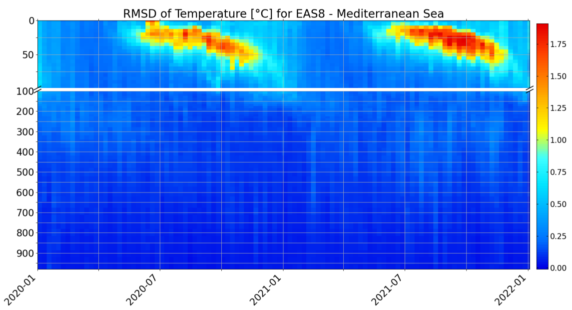

Figure 4*: Hovmöller (depth [m] vs time) diagram of monthly mean RMSD for temperature averaged over the entire Mediterranean Sea (T-<X-Y>m-W-CLASS4–PROF-RMSD-MED- Jan2020-Dec2021-HOV).*

Commented [EiC84]: These are shown in the figure. Suggest deleting.

Commented [EiC85]: ?

Commented [ACG86R85]: The technical description of the metrics used in the QUID (bias and RMSD) can be found in the Scientific Qualification Plan (ScQP) document. We are required to use this metrics in the QUID by Mercator and refer to them using their names.
(See Table 7)

Commented [EiC87R85]: This does not prevent you from adding an explanatory remark for users not familiar with the ScQP.

Commented [EiC88]: ? Is this the name of a dataset in the CMEMS catalogue? Unclear. Please add corresponding info.

Commented [ACG89R88]: The technical description of the metrics used in the QUID (bias and RMSD) can be found in the Scientific Qualification Plan (ScQP) document. We are required to use this metrics in the QUID by Mercator and refer to them using their names.
(See Table 7)

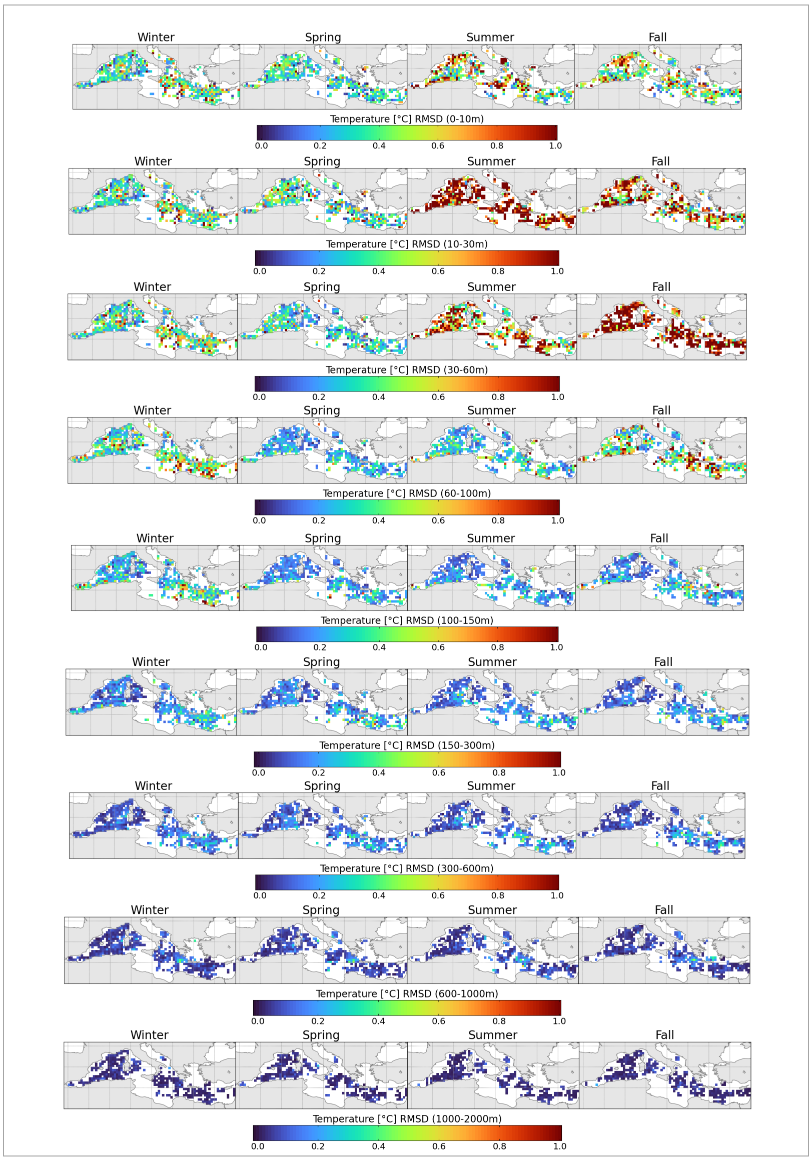

***Figure 5**: Maps of temperature RMSD in different parts of the Mediterranean computed based on the 2-year qualification period from 2020 to 2021 for different layers (T-<X-Y>m-2Y-CLASS4–PROF-RMSD/BIAD-TS- Jan2020-Dec2021-2DMAP).*

Commented [EiC90]: "respectively" is non-sensical here. Deleting.

Commented [EiC91]: As above.

Commented [ACG92R91]: The technical description of the metrics used in the QUID (bias and RMSD) can be found in the Scientific Qualification Plan (ScQP) document. We are required to use this metrics in the QUID by Mercator and refer to them using their names.
(See Table 7)

SST RMSD is higher during the warm season and exhibits a minimum during spring (**Figure 6**). SST bias (observations – model) is generally negative meaning that the model overestimates SST. It should be noted that here daily mean EAS8 system outputs are compared to foundation SST (i.e., SST values collected close to midnight).

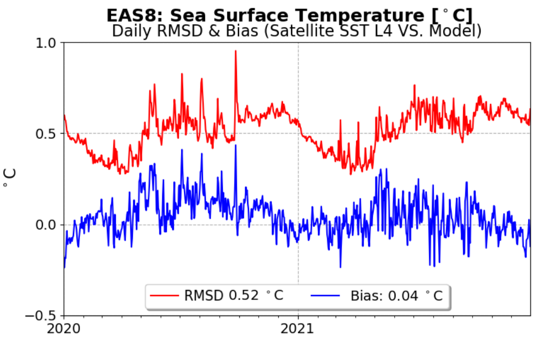

Figure 6: *Time series of 2-weekly SST RMSD and Bias (observations – model) (SST-D-CLASS4-RAD-RMSD-Jan2019-Dec2019, SST-D-CLASS4-RAD-BIAS-Jan2019-Dec2019) with respect to satellite L4 data at 1/16° resolution.*

IV.2 Seabed temperature

Monthly climatologies of bottom temperature, defined as the temperature of the deepest level in the circulation model, have been compared to SeaDataNet climatologies (see Tonani et al., 2013 for more details) for the period 2020-2021.

The system is able to reproduce the seasonal variability of bottom temperature, although yielding slight overestimations of absolute values (Figure 7).

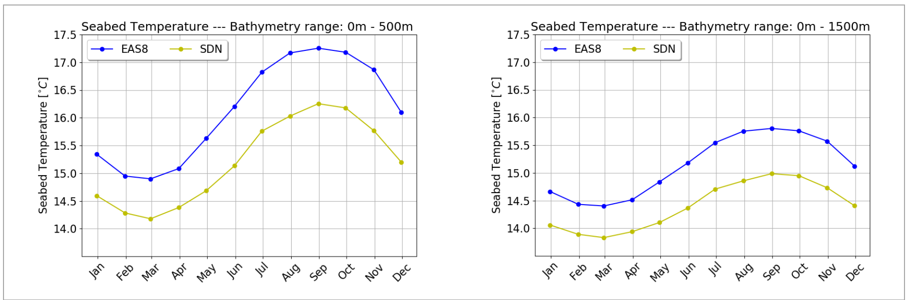

Figure 7: *Time series of seabed temperature monthly climatologies from SeaDataNet dataset (SDN) and EAS8 system for a 0-500m (left) and 0-1500m (right) bathymetry range (SBT-D-CLASS4-CLIM-MEAN_M-MED).*

Comparing climatology maps for different months (Figure **8**), it can be seen that EAS8 exhibits similar temporal and spatial patterns compared to the climatological datasets, although it predicts warmer seabed temperatures in several coastal areas.

Commented [EiC93]: This is somewhat unconventional as BIAS is usually defined as the system to be validated minus the value used for comparison (i.e., model - observations). This ensures that the results are easily understood, e.g., a positive bias is understood as the model overestimating the data. In your case this is reversed, leading to counterintuitive results, e.g., a positive bias means the model underestimates observations, making this an unfortunate choice for calculating bias. Consider changing this in future updates of this document.

Commented [ACG94R93]: We are REQUIRED by MERCATOR to define the bias as observation – model. It is not our own choice. In case, we can change the definition from the next QUID version.

Commented [EiC95]: Obvious from legend. Deleting.

Commented [EiC96]: I would suggest to add this here as your method of calculating bias is a little unorthodox (see above comment), so user only looking at your figure without reading the main text will draw the wrong conclusions unless you provide this info.

Commented [ACG97R96]: We are REQUIRED by MERCATOR to define the bias as observation – model. It is not our own choice. In case, we can change the definition from the next QUID version.

Commented [EiC98]: All contained in the figure. Deleting.

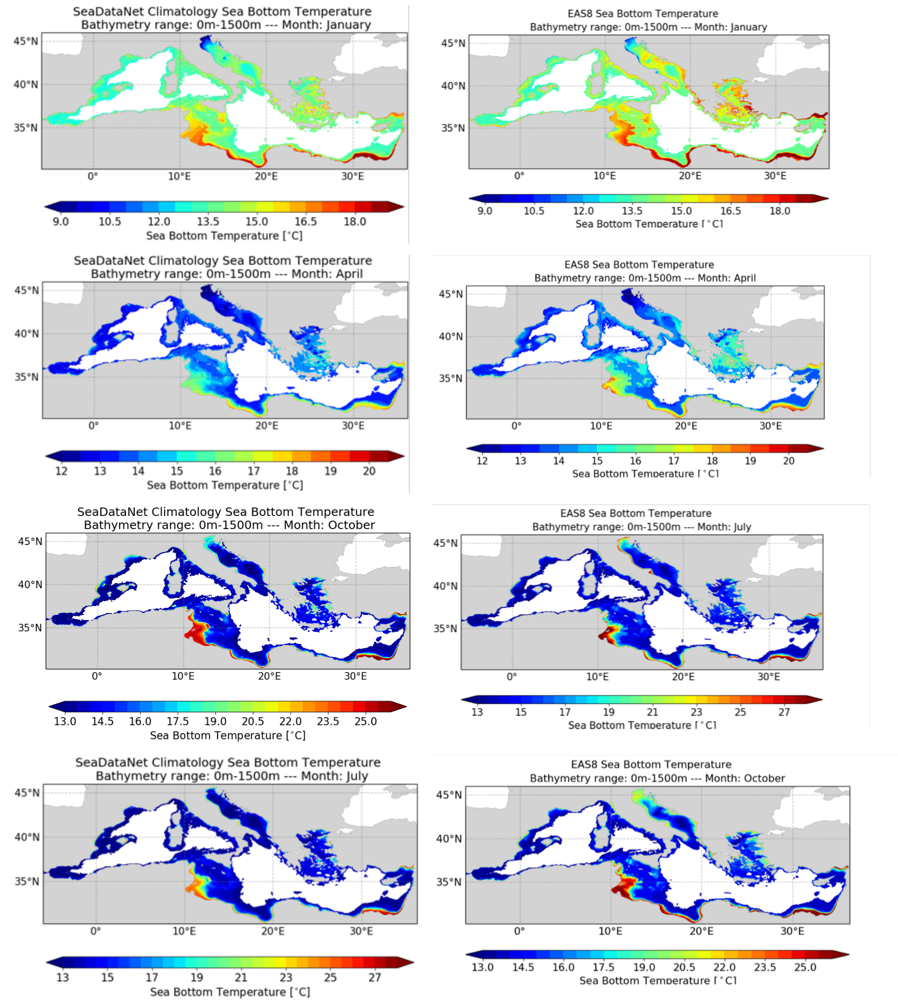

***Figure 8**: Comparing seabed temperature climatologies from SeaDataNet (left column) and EAS (right column) for different months and the bathymetry range 0-1500 m (SBT-D-CLASS1-CLIM-MEAN_M-MED).*

Commented [EiC99]: I have combined all these figures into a single one (deleting what were Figures 9 to 11). So now there is just 1 caption and figure number instead of 4 captions that are basically repeating the same text. I also updated all cross-reference and the figure counter.

Since your panels on the right were displayed in a different aspect ratio/size. I tried to fix this by cropping the individual pictures. Please check.

Commented [ACG100R99]: Ok, done

IV.3 Salinity

Table 9 summarises the quality metrics for salinity with respect to quasi-independent (ARGO) data assimilated by the system.

The validation is based on the two-year period 2020-2021 and is provided at 5 depths (8, 30, 150, 300, and 600 m). RMSD is always below 0.19 PSU, with the highest values obtained for the topmost layers and values decreasing significantly below 150 m (Table 8).

Variables/estimated accuracy:	Metrics		Depth	Observation
	RMSD [PSU]	BIAS [PSU]	[m]	Instrument
SALINITY	0.19	-0.008	8	Argo
	0.18	-0.004	30	Argo
	0.10	0.000	150	Argo
	0.04	-0.001	300	Argo
	0.03	0.003	600	Argo

Table 9: *Quasi-independent validation. EANs Analysis evaluation based over the two-years period 2020-2021.*

The salinity error is generally higher above 30 m with mean values less than 0.20 PSU and better skill below 150 m with mean values lower than 0.1 PSU as can be observed in **Figure 9**.

Monthly mean RMSD of salinity are shown in Figure 10 as Hovmöller diagrams. Clearly, RMSD is higher near the surface and decreases with increasing depth, especially from about 150 m onward.

In addition to basin averaged statistics, the following panels in Figure 11 show the spatial pattern of the salinity RMSD (EANs) per season and per vertical layer, computed over the entire qualification period (2020-2021) with respect to ARGO data, S-<X-Y>m-2Y-CLASS4–PROF-RMSD/BIAS-TS-Jan2020-Dec2021-2DMAP. The maps confirm that the largest discrepancy appears in the upper layers and decrease below 100 meters depth.

Commented [EiC101]: I am not sure I understand this correctly. You are calculating RSMD with respect to the same data that you use in data assimilation? Please check my edit.

Commented [ACG102R101]: As explained on pag. 18: "Quasi-independent data are all the observations (Satellite SLA and SST and in situ vertical profiles of temperature and salinity from XBT and Argo) which are assimilated into the system. Diagnostic in terms of RMS of the misfits and/or bias are computed using the model fields before the ingestion of the observations and applying the increments."

Commented [EiC103]: As your document is longer than the recommended 50 pages, I continue to try and reduce verbosity whenever possible, also by deleting repeated or superfluous information like here. You could consider applying similar changes throughout the document to reduce the document length.

Commented [ACG104R103]: Thanks, for your suggestion. We will keep in mind, especially for the next QUID versions.

Commented [EiC105]: Either "validation" or "qualification" but you are not providing a "synthesis". Please check the meaning of this word.

Commented [ACG106R105]: Ok, done

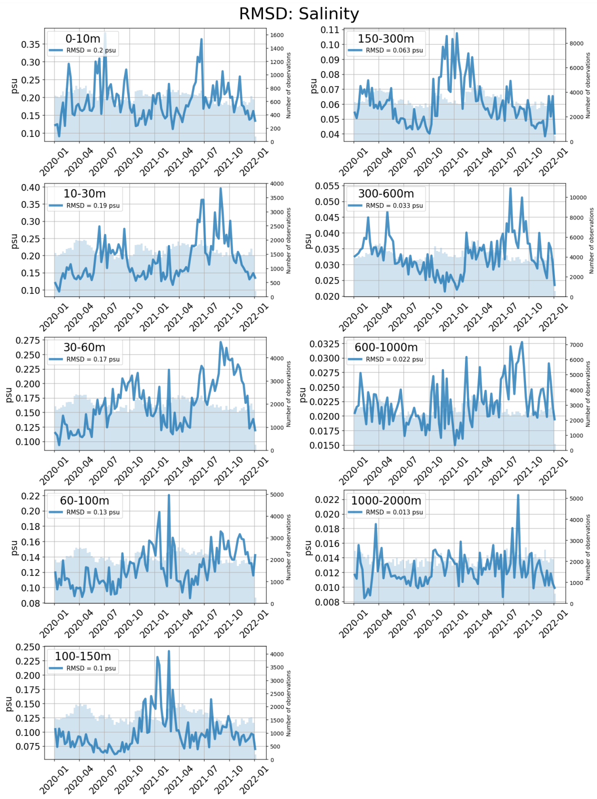

Figure 9: *Time series of weekly salinity RMSD for different vertical layers. Shaded areas indicate the number of available observations (profiles) (S-<X-Y>m-2W-CLASS4- ASSIM–PROF-RMSD-MED-Jan2020-Dec2021).*

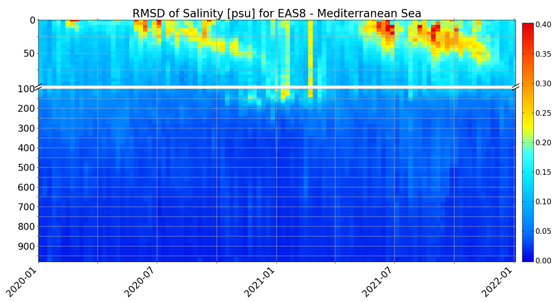

Figure 10: *Hovmöller (depth [m] vs time) diagram of monthly mean salinity RMSD averaged over the whole Mediterranean Sea for the two-year period 2020-2021 (S-<X-Y>m-2W-CLASS4–PROF-RMSD-MED- Jan2020-Dec2021-HOV).*

Commented [EiC107]: There is a confusing legend "EAS8". Please remove.

Commented [ACG108R107]: Done

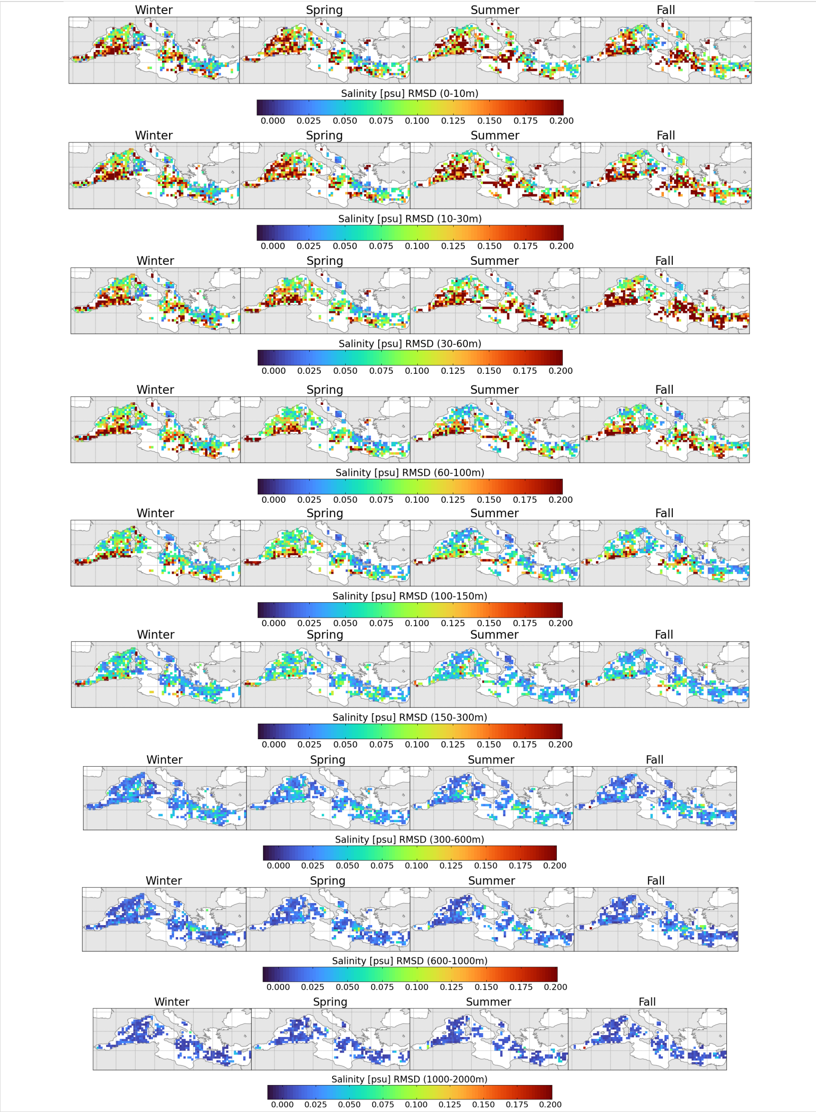

***Figure 11**: Seasonal averages of salinity RMSD for the qualification period (2020-2021) and different vertical layers (S-<X-Y>m-2Y-CLASS4–PROF-RMSD/BIAS-TS- Jan2020-Dec2021-2DMAP).*

Commented [EiC109]: Is this what you are showing? Please check.

Commented [ACG110R109]: Yes, they are!

Commented [EiC111]: Do you mean "averaged"?

Commented [EiC112]: ? I cannot see any number in the top-left of each row

Commented [ACG113R112]: Done

IV.4 Sea Level

Table 10 shows the RMSDs for SLA with respect to each available satellite (along-track observations) from January 2020 to December 2021.

Satellite	SLA RMSD [cm]	Availability	# of missing days
All Satellites	2.7	01/01/2020-31/12/2021	0
ALTIKA	2.6	01/01/2020-31/12/2021	2
CRYOSAT 2	2.8	01/01/2020-31/12/2021	20
JASON 3	2.7	01/01/2020-31/12/2021	17
SENTINEL 3A	2.7	01/01/2020-31/12/2021	0
SENTINEL 3B	2.7	01/01/2020-31/12/2021	0
HY-2A	3.1	01/01/2020-09/06/2020	5
HY-2B	2.8	01/01/2020-31/12/2021	103

Table 10: *RMSDs based on the two-year time series 2020-2021 for sea level anomaly (SAL) for each available satellite.*

Commented [EiC114]: ?

Figure 12 depicts the SLA misfits RMSD and bias per season (EANs), computed with respect to satellite data on the entire qualification period 2020-2021 along with the number of available observations per region.

Commented [EiC115]: Again you are just paraphrasing the caption instead of providing an interpretation. Please delete and replace with actual interpretation of results (see my edit for Fig. 9 above).

Commented [ACG116R115]: Consider that we do not always have an interpretation. And the interpretation of the results is out of the scope of the QUID document which should just provide validation metrics values. In my opinion a user can deduct his own interpretation by the Figure.

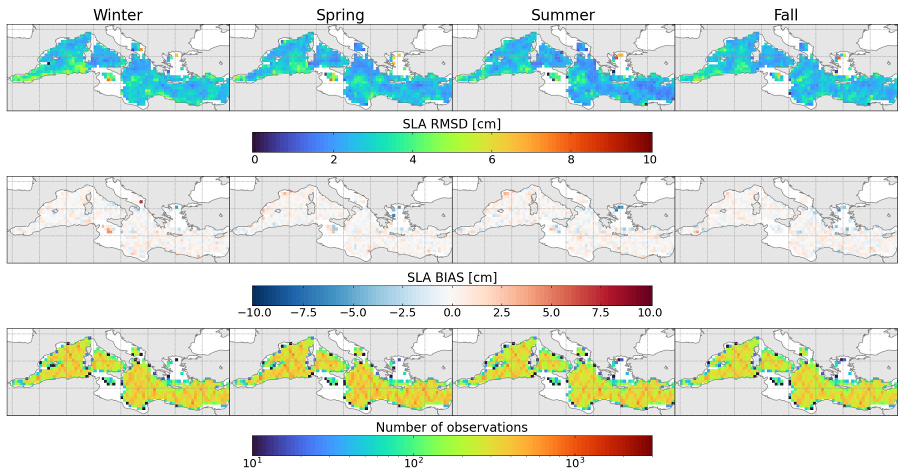

Figure 12*: Seasonal maps of SLA RMSD (top row), bias before bias removal (second row) and number of observations (third row) for satellite data available during the qualification period 2020-2021 (SLA-<X-Y>m-2Y-CLASS4–PROF-RMSD/BIAS-TS- Jan2020-Dec2021-2DMAP).*

The following Figure 13 shows the time series of weekly RMS differences and bias (before removal) of sea level anomaly EANs, SLA-SURF-W-CLASS4-ASSIM-ALT-RMSD/BIAS-MED-Jan2020-Dec2021. The number of assimilated data is provided as shaded area. The system has an overall RMSD of about 2.7 cm in the whole basin.

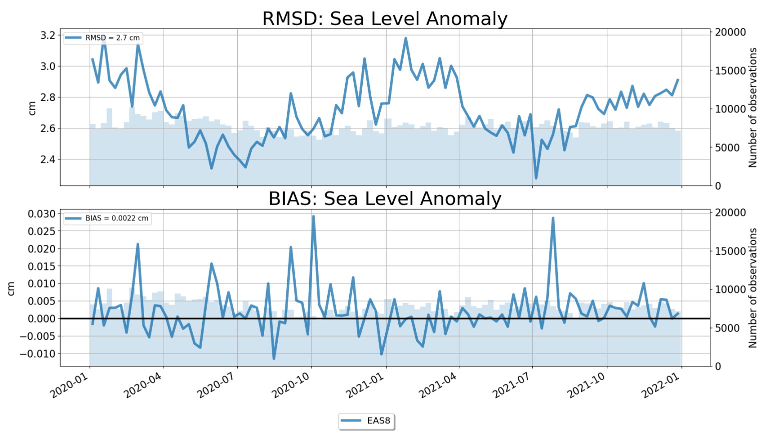

Figure 13: *Time series of weekly RMSD and bias before bias removal along SLA data track for all satellites shown in Table 10. Shaded areas indicated the corresponding number of assimilated data (SLA-SURF-2W-CLASS4- ASSIM-ALT-RMSD-MED-Jan2020-Dec2021).*

IV.5 Currents

Model skill for sea surface currents is assessed using coastal moorings and HF radars.

Table 11 summarizes the RMSD and bias with respect to in-situ data for the period 2020-2021, namely six coastal moored buoys and four HF-radars. Figure 14 shows a scatter plot of the model output vs observed values, together with the resulting statistics (UV-SURF-D-CLASS2-MOOR-mean-SC). The location of the instruments is shown in Figure 15. Observations provide current estimates for the top 3m only. Due to the reduced number of observations, mainly located in coastal areas in the western part of the basin, the statistical robustness of this analysis is poor.

Figure 16 shows the RMSD and bias of daily sea surface currents time series of EAS8 computed with respect to available moorings in the period 2020-2021, the figure includes also the mean values.

Variable	Reference	RMSD	Bias	Depth range	# of available instruments
EAS8 Currents	Moorings	0.12 m/s	0.04 m/s	0-3 m	6
EAS8 Currents	HF Radars	0.12 m/s	-0.03 m/s	Surface	4

Table 11: *Quality metrics with respect to moored buoys and HF-radars for the 2020-2021 period.*

Commented [EiC117]: As above. Delete and add interpretation of results shown in figure.

Commented [EiC118]: ?

Commented [ACG119R118]: This are the basics of Data assimilation theory. In my opinion, explaining how it works would require too many lines, and is out of the scope, for the QUID document.

Commented [EiC120]: Replace with interpretation of results.

Commented [ACG121R120]: Consider that we do not always have an interpretation. And the interpretation of the results is out of the scope of the QUID document which should just provide validation metrics values. In my opinion a user can deduct his own interpretation by the Figure.

Commented [EiC122]: Replace with interpretation.

Commented [ACG123R122]: Consider that we do not always have an interpretation. And the interpretation of the results is out of the scope of the QUID document which should just provide validation metrics values. In my opinion a user can deduct his own interpretation by the Figure.

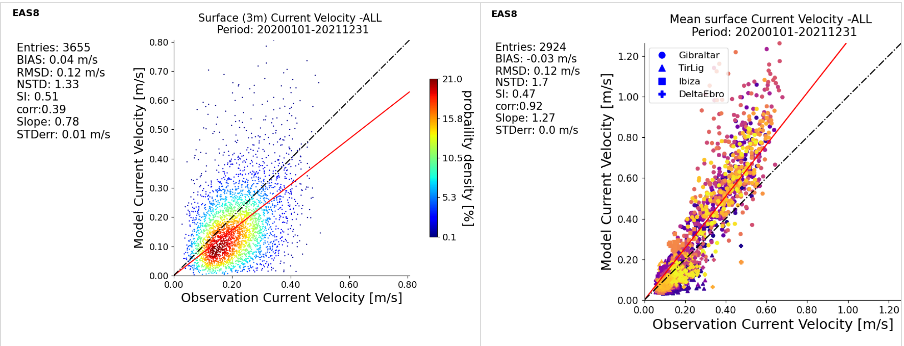

***Figure 14:** Scatter plot of EAS8 vs observed current velocities in 2020-2021 with respect to mooring data (left panel) and HF-radar (right panel). In the right panel, different symbol colours correspond to different dates and different symbol shapes represent different HF radar locations (UV-SURF-D-CLASS2-MOOR-mean-SC).*

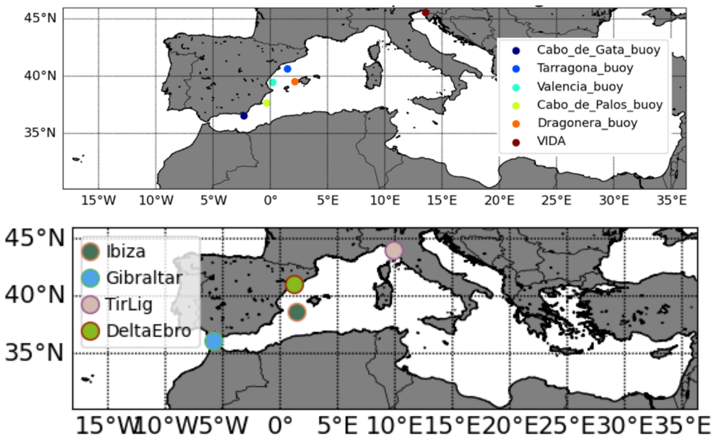

***Figure 15:** Location of the six moorings available for validation in 2020-2021 (upper panel) and of the four available HF-radars (lower panel).*

Commented [EiC124]: ? What day? Do you mean "date"? Missing colour bar/legend.

Commented [ACG125R124]: Yes, date. Done. One colour for each date.

Commented [EiC126R124]: Then this should be stated in the caption, not in your reply to my comment. I have added some new content to make this clearer.

Commented [EiC127]: ?

Commented [ACG128R127]: The technical description of the metrics used in the QUID (bias and RMSD) can be found in the Scientific Qualification Plan (ScQP) document. We are required to use this metrics in the QUID by Mercator and refer to them using their names. (See Table 7)

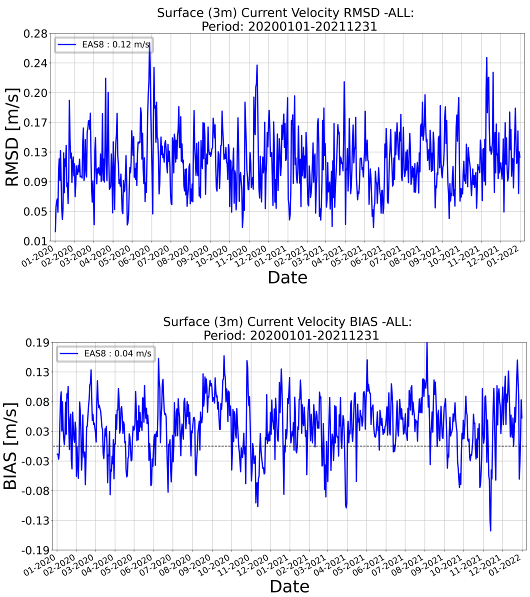

***Figure 16**: Time series of RMSD (upper panel) and bias (lower panel) of surface currents with respect to the available mooring data in the period 2020-2021 (UV-SURF-D-CLASS2-MOOR-RMSD-Jan2020-Dec2021, UV-SURF-D-CLASS2-MOOR-BIAS-Jan2020-Dec2021).*

We also assessed some derived quantities such as transport through the Strait of Gibraltar.

In Figure 17 the time series of the mean daily net, eastward and westward fluxes through the Gibraltar Strait in the 7-years period 2016-2021 are represented. The values of the transports are computed by means of a post-processing procedure based on daily values.

Commented [EiC129]: Replace with interpretation.

Commented [ACG130R129]: Consider that we do not always have an interpretation. And the interpretation of the results is out of the scope of the QUID document which should just provide validation metrics values. In my opinion a user can deduct his own interpretation by the Figure.

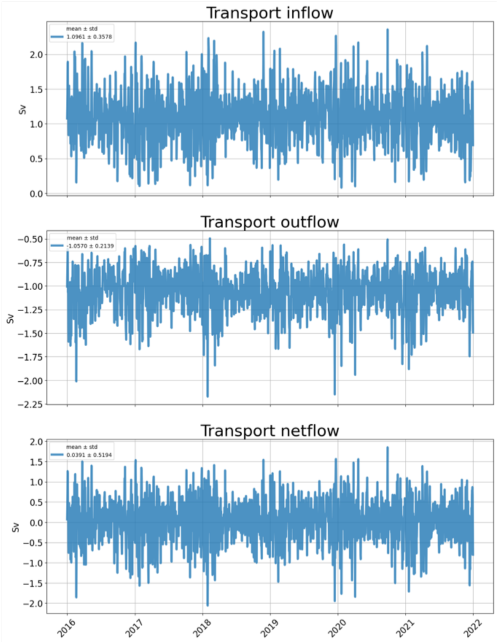

***Figure 17**: Time series of daily mean Net (bottom panel), Eastward (top panel) and Westward (second panel) fluxes through the Strait of Gibraltar for period 2016-2021.*

Table **12** provides a comparison of these fluxes with respect to literature values (Soto-Navarro et al., 2010) that are based on currents form October 2004 to January 2009 crossing 5°58.60' W. To allow more direct comparisons, we also compared these literature values to longer model runs that cover the same period. While the net transport is in agreement with literature values, the model tends to slightly overestimate the absolute net volume transports in both directions.

Gibraltar Mean Transport	EAS8 (2020-2021)	EAS8 (2016-2021)	Soto-Navarro et al., 2010
Net	0.039 Sv	0.039 Sv	0.038 ± 0.007 Sv
Eastward	1.091 Sv	1.096 Sv	0.81 ± 0.06 Sv
Westward	1.052 Sv	1.057 Sv	0.78 ± 0.05 Sv

***Table 12**: Gibraltar strait mean fluxes across the 5°48' W for EAS8 system averaged over 2020-2021 and 2016-2021 values (Soto-Navarro et al. 2010): TRANSP-D-CLASS3-LIT-MEAN-GB-VAL.*

Commented [EiC131]: This would be an example for an interpretation of results. This is missing for all the above figures.

Commented [ACG132R131]: Ok

Commented [ACG133]: Sorry, but your modification is uncorrect! Transports are more reliable when computed on periods lasting several years. The result is more robust. However, since we are analyzing 2020-2021 it is important also to provide the result for this period.

Commented [EiC134R133]: OK.

IV.6 Mixed Layer Depth

EAS8 skill to accurately represent mixed layer depth (MLD) is assessed through 2D maps of monthly averaged MLDs computed over the five-year period 2017-2021 through a comparison to a dataset of monthly climatologies based on MBT, XBT, profiling floats, gliders, and ship-based CTD observations collected between 1969 and 2013 (Houpert et al., 2015) (Figure 18 to Figure 21).

In February (Figure 18), the deepening of the MLD in the Gulf of Lyon and South Adriatic areas is well represented by the EAS8 system, although the modelled MLD in the Aegean Sea is deeper than in the climatological means. During June and August (Figure 19: and Figure 20:) the modelled MLD is in good overall agreement with the climatological means, yielding only a slight overestimation of MLD especially in June. In December (Figure 21:) the deepening of the MLD is well represented by the EAS8 system, with some overestimations in the Gulf of Lyon and Adriatic and Aegean Seas.

In general, the EAS8 system is able to represent the spatial and seasonal distribution of the MLD. The main differences with regard to observations are likely due to the low spatial resolution of the climatological dataset which does not cover the whole Mediterranean Sea and contains data from time periods different to our period of evaluation. These may be factors that affect accuracy, especially considering that the Mediterranean is characterized by areas of deep-water formation whose deepening can significantly vary in time.

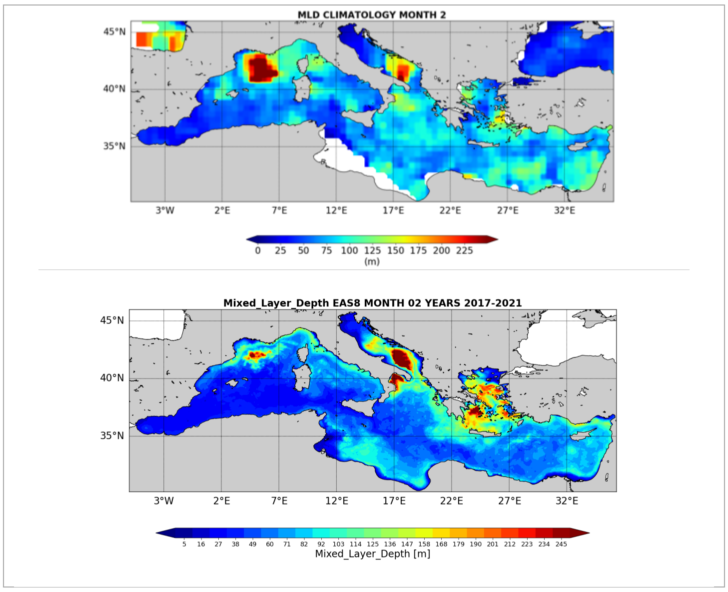

Figure 18: February MLD maps. Top: climatological data from literature; bottom: February 2017-2021 monthly averaged MLD from MED-Physics EAS8 system: MLD-D-CLASS1-CLIM-MEAN_M-MED.

Commented [EiC135]: Remove colon
Commented [ACG136R135]: Done
Commented [EiC137]: ? Remove the colon.
Commented [ACG138R137]: Done
Commented [EiC139]: Temporal? Spatial? Spatio-temporal?
Commented [ACG140R139]: Done (but quite obvious!)
Commented [EiC141R139]: If you say so.

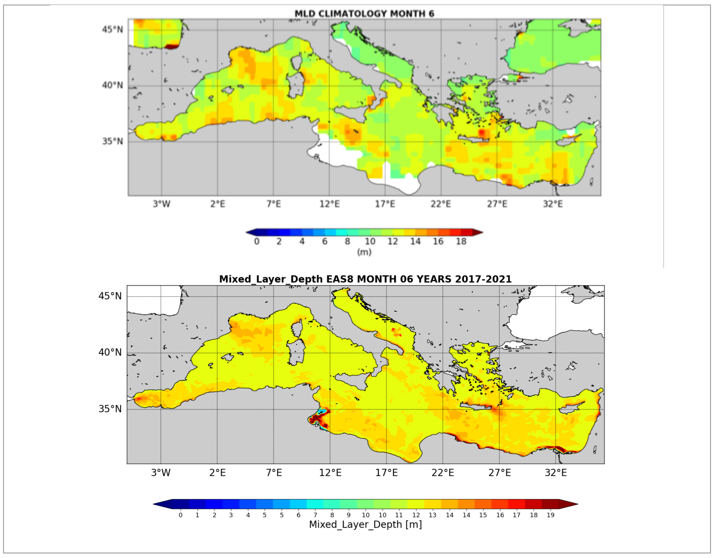

Figure 19: *June MLD maps. Top: climatological data from literature; bottom: June 2017-2021 monthly averaged MLD from MED-Physics EAS8 system: MLD-D-CLASS1-CLIM-MEAN_M-MED.*

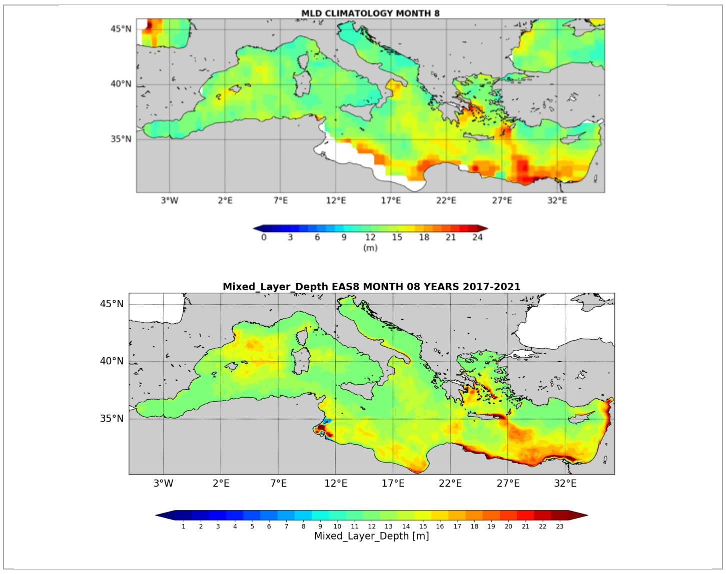

Figure 20: *August MLD maps. Top: climatological data from literature; bottom: August 2017-2021 monthly averaged MLD from MED-Physics EAS8 system: MLD-D-CLASS1-CLIM-MEAN_M-MED.*

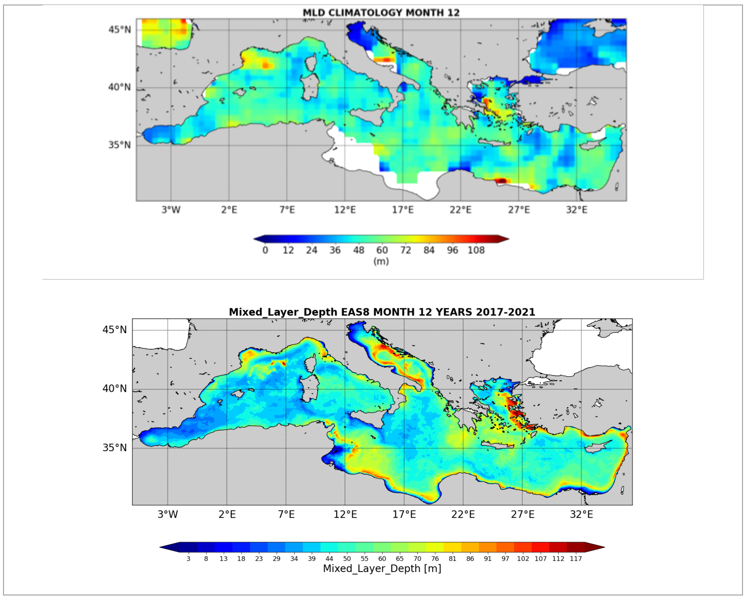

Figure 21: *December MLD maps. Top: climatological data from literature; bottom: December 2017-2021 monthly averaged MLD from MED-Physics EAS8 system: MLD-D-CLASS1-CLIM-MEAN_M-MED.*

IV.7 Harmonic Analysis

A harmonic analysis has been performed to evaluate the skill of the EAS8 system to represent tidal amplitudes and phases of each tidal component. The harmonic analysis is based on a six-month period of hourly sea level fields. Figure 22 shows the locations of tide gauges used for this analysis while Table 13 provides the corresponding location information.

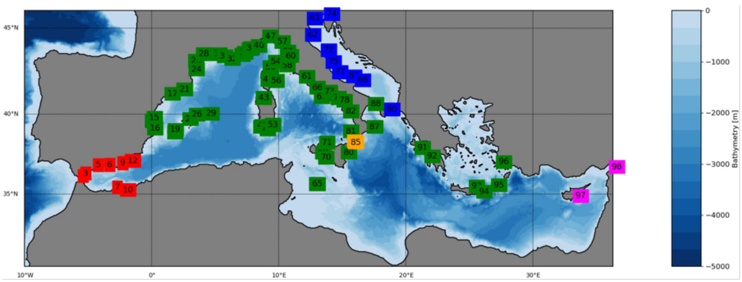

Figure 22*: Location of the Mediterranean tide gauges used to perform the harmonic analysis. Different colours represent different areas of the basin, while the numbers refer to the tide gauges listed in* ***Table 13****.*

Commented [EiC142]: Moved here as this should be in the caption and not in the main text.

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Name	Label	Longitude	Latitude
TarifaTG	1	-5.6036	36.0064
IOC_alge	2	-5.3984	36.177
AlgecirasTG	3	-5.3983	36.1769
IOC_mal3	4	-4.4171	36.7118
MalagaTG	5	-4.417	36.712
IOC_motr	6	-3.5236	36.7202
MelillaTG	7	-2.918	35.291
Almeria2TG	8	-2.4809	36.8319
IOC_alme	9	-2.4784	36.83
IOC_said	10	-2.2929	35.1119
CarbonerasTG	11	-1.8996	36.9743
IOC_carb	12	-1.8996	36.9743
ValenciaTG	13	-0.33	39.46
IOC_vale	14	-0.3113	39.442
SaguntoTG	15	-0.206	39.634
GandiaTG	16	-0.152	38.995
TarragonaTG	17	1.2132	41.0789
FormenteraTG	18	1.4189	38.7347
IbizaTG	19	1.4497	38.9111
BarcelonaTG	20	2.163	41.342
IOC_barc	21	2.1657	41.3418
PalmadeMallorcaTG	22	2.6375	39.5603
PortLaNouvelleTG	23	3.0641	43.0147
IOC_ptve	24	3.1073	42.5201
IOC_alcu	25	3.139	39.8346
AlcudiaTG	26	3.1392	39.8347
IOC_sete	27	3.6991	43.3976
SeteTG	28	3.7017	43.4
MahonTG	29	4.2706	39.893
FosSurMerTG	30	4.8929	43.4049
MarseilleTG	31	5.3537	43.2785
IOC_toul2	32	5.9131	43.1172
PortFerreolTG	33	6.7176	43.3591
IOC_figu	34	6.9338	43.4835
IOC_figu2	35	6.9338	43.4835
LaFigueiretteTG	36	6.9338	43.4835
IOC_nice2	37	7.285	43.695
NiceTG	38	7.2855	43.6956
MonacoTG	39	7.4237	43.733
IOC_IM01	40	8.0188	43.8769
TAD_ISPRA-17	41	8.1829	39.0837
IOC_CF06	42	8.3081	39.1436
RMN-PortoTorres	43	8.4039	40.8422
TAD_IDSL-09	44	8.7195	38.9275
AjaccioTG	45	8.7629	41.9227
IOC_GE25	46	8.9255	44.4101
RMN-Genova	47	8.9255	44.4101
IleRousseTG	48	8.9352	42.6396
IOC_rous2	49	8.9381	42.6356
IOC_rous	50	8.9381	42.6356
IOC_CA02	51	9.1142	39.2101
RMN-Cagliari	52	9.1142	39.2101
TAD_ISPRA-07	53	9.1143	39.2102
CenturiTG	54	9.3498	42.9658
IOC_sole2	55	9.3738	41.8358
SolenzaraTG	56	9.4038	41.8569
IOC_LA38	57	9.8576	44.0966
RMN-MarinaDiCampo	58	10.2383	42.7426
RMN-Livorno	59	10.2993	43.5463
TAD_ISPRA-14	60	10.5333	43.2913
RMN-Civitavecchia	61	11.7896	42.094
RMN-Ravenna	62	12.2829	44.4921
RMN-Venice	63	12.4265	45.4182
TAD_ISPRA-11	64	12.604	35.5
IOC_LA23	65	12.6044	35.4998
RMN-Anzio	66	12.6348	41.4469
RMN-Ponza	67	12.9656	40.8952
RMN-Sciacca	68	13.0765	37.5045
TAD_ISPRA-12	69	13.0765	37.5045
TAD_ISPRA-16	70	13.3128	37.1725
RMN-Palermo	71	13.3713	38.1214
RMN-Ancona	72	13.5065	43.6248
RMN-Gaeta	73	13.5897	41.21
RMN-Trieste	74	13.7561	45.6544
RMN-SBenedettoDelTronto	75	13.8898	42.9551
RMN-Napoli	76	14.2692	40.8397
RMN-Ortona	77	14.4149	42.3559
TAD_ISPRA-03	78	14.7508	40.6766
IOC_CT03	79	15.0938	37.498
RMN-Catania	80	15.0938	37.498
TAD_ISPRA-01	81	15.2517	38.8173
RMN-Palinuro	82	15.2753	40.0299
RMN-IsoleTremiti	83	15.5016	42.1189
TAD_ISPRA-10	84	15.5635	38.1963
TAD_ISPRA-09	85	15.6489	38.1217
RMN-Vieste	86	16.177	41.8881
TAD_ISPRA-08	87	17.137	39.0816
RMN-Taranto	88	17.2238	40.4756
RMN-Otranto	89	18.4969	40.1464
TAD_ISPRA-15	90	18.497	40.146
TAD_NOA-07	91	20.9052	37.7814
TAD_NOA-08	92	21.6644	37.2596
TAD_NOA-10	93	25.1525	35.3484
TAD_NOA-04	94	25.7385	35.0037
TAD_NOA-03	95	26.9218	35.4186
TAD_IDSL-25	96	27.2878	36.8984
IOC_zygi1	97	33.3402	34.7263
IOC_iske	98	36.1768	36.5942

Table 13: *List of the 98 EMODnet tide gauges used to perform the harmonic analysis. Colours correspond to different areas of the basin (see Figure 22:). Bold font is used to identify tide gauges whose data is available in literature.*

The results indicate a very good agreement between the model and observations (**Figure 23**). In some location, model predictions of tidal amplitudes and phases deviate from observation values by several centimetres/degrees. Since the amplitudes of the diurnal components K1 and O1 are below 20 and 10 cm, respectively, these differences are non-negligible especially for the O1 component.

Commented [EiC144]: Remove colon.

Commented [EiC145]: "is available in" or "was taken from"?

Commented [ACG146R145]: Is available. The values are observed (not taken from literature!). But these locations in bold correspond to the tide-gauge for which we could find values also from literature

Commented [ACG147]: Since your sentence was a little oversimplified, I had to include some details

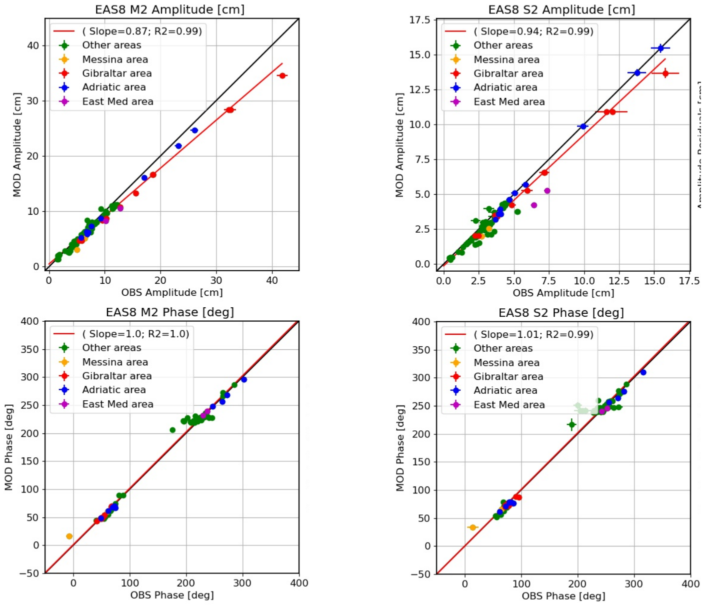

***Figure 23**: Scatter plot of tidal amplitude and phase for the four major Mediterranean Sea tidal constituents: M2, S2, K1, O1 evaluated using date from 98 tide gauges: SL-SURF-D-CLASS2-TG-MEAN-SC (continues on next page). The error bars are bootstrapped 95% confidence intervals based on an uncorrelated bivariate coloured-noise model*

Commented [EiC148]: OK. So this answers my previous comment. Move this to caption.

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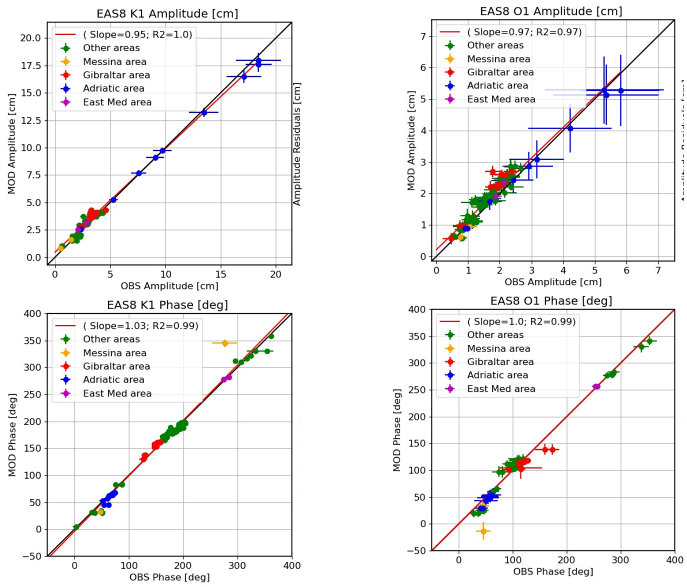

Figure 23 (continued): *Scatter plot of tidal amplitude and phase for the 4 major Mediterranean Sea tidal constituents: M2, S2, K1, O1 evaluated at 98 tide gauges: SL-SURF-D-CLASS2-TG-MEAN-SC. The error bars are bootstrapped 95% confidence intervals based on an uncorrelated bivariate coloured-noise model*

Commented [EiC150]: OK. So this answers my previous comment. Move this to caption.

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A plot of the RMS misfits (Figure 24:) shows that the model shows the largest deviation for the M2 component, which is the constituent with highest amplitude throughout most of the domain.

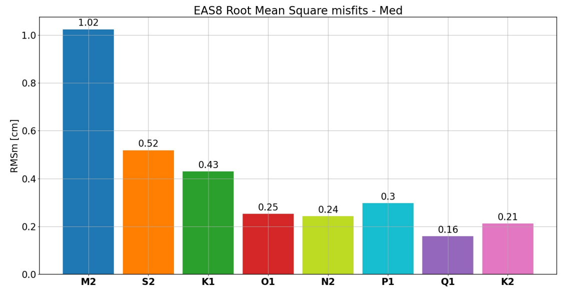

Figure 24: *RMS misfits of vectorial distances between model and tide gauge tidal amplitudes for each tidal constituent: SL-SURF-D-CLASS2-TG-RMS-VAL.*

A further analysis has been performed by evaluating the vectorial distances between the model and a sub-set of 35 tide gauges (marked in bold in Table 13) which are used in the literature for model validations (Tsimplis et al., 1995; Palma et al., 2020) (Table 14). The results show that for this sub-set, EAS8 is almost always closer to observations than previous studies, especially for the diurnal K1 tidal component.

Commented [EiC152]: For a user to follow this conclusion, you would have to present the corresponding values from the "previous studies".

Commented [ACG153R152]: You can find them in the following Table!

Commented [EiC154R152]: Then you should maybe reference the table (as you have done now). Otherwise users have to guess.

Mean Vectorial distances	M2	S2	K1	O1
EAS8	1.20 cm	0.64 cm	0.62 cm	0.37 cm
Tsimplis et al., 1995	1.60 cm	0.98 cm	1.35 cm	0.41 cm
Palma et al., 2020	1.53 cm	0.86 cm	1.34 cm	0.71 cm

***Table 14**: Mean vectorial distances between model and a subset of 35 tide gauges (marked in bold in Table 13): SL-SURF-D-CLASS2-LIT-VECD-VAL.*

Finally, the EAS8 harmonic analysis results have been compared to the TPXO9 tidal barotropic model solutions (Table 15).

Commented [EiC155]: Add your interpretation/conclusion.

Commented [ACG156R155]: Consider that we do not always have an interpretation. And the interpretation of the results is out of the scope of the QUID document which should just provide validation metrics values. In my opinion a user can deduct his own interpretation by the Figure.

Tidal Component	Root Mean Square Misfits
M2	1.57 cm
S2	1.08 cm
K1	0.48 cm
O1	0.22 cm
N2	0.27 cm
P1	0.19 cm
Q1	0.10 cm
K2	0.43 cm

***Table 15**: RMS misfits of vectorial distance between EAS8 harmonic analysis results on the whole Mediterranean Basin and the global TPXO tidal solution: SL-SURF-D-CLASS2-TPXO-RMS-VAL.*

The maps shown in Figure 25 provide a means to assess the spatial variations in tidal amplitude BIAS for the four main tidal constituents. Red areas represent regions where EAS8 overestimates the amplitude from TPXO9, while areas of underestimation are marked in blue. Overall, the EAS8 harmonic analysis results are close to the those from TPXO9 with the exception of the Gulf of Gabés, off Tunisia, where M2 amplitude differences reach more than 4 cm. However, this particular area is characterized by a strong tidal signal with M2 tidal amplitudes exceeding 25 cm, making the relative deviation comparable to other regions.

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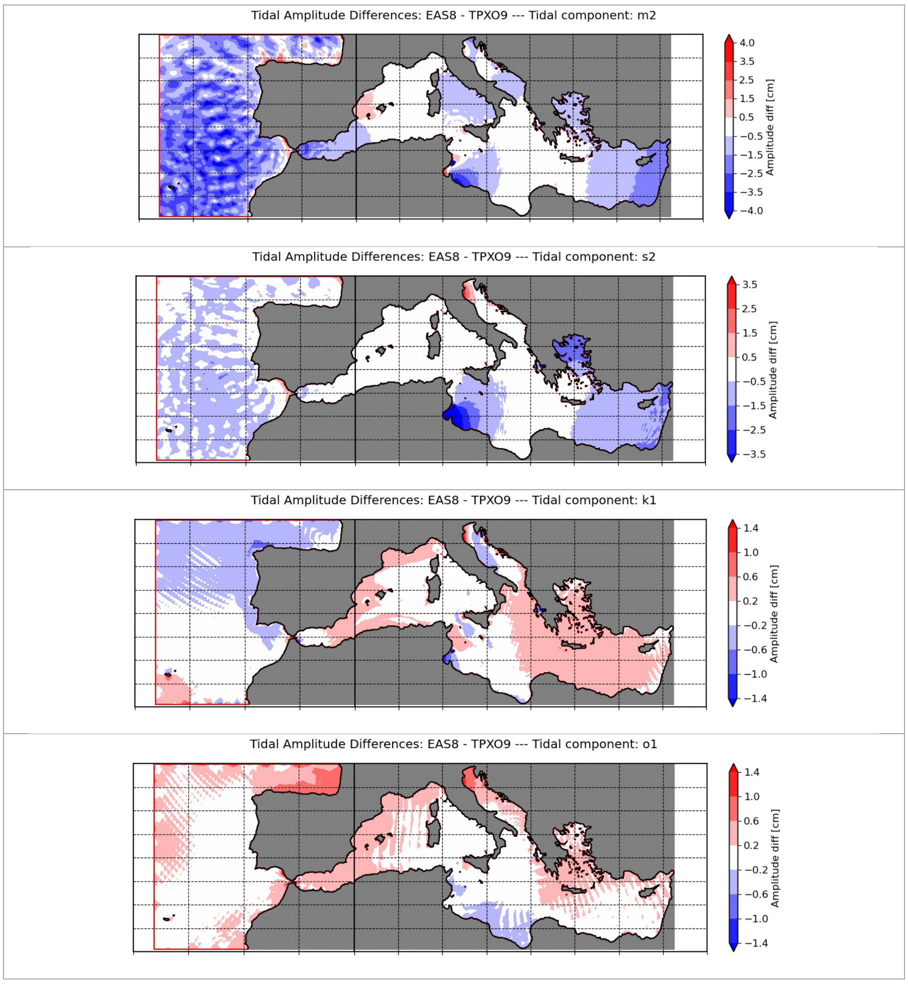

Figure 25: *Tidal amplitude differences between EAS8 and the TPXO9 model: SL-SURF-D-CLASS4-TPXO-AMP-2DMAP.*

V SYSTEM'S NOTICEABLE EVENTS, OUTAGES OR CHANGES

Date	Change/Event description	System version	other
8 July 2019 EIS	Updated SST nudging; Included assimilation S3B; Lateral open boundary conditions at the Dardanelles Strait.	EAS4	Time series availability: 01/01/2017 to 30 May 2020
30 March 2020 EIS	Model daily data centred at 12.00 UTC (instead 00:00 UTC).	EAS5	Time series availability: From 01/01/2018
15 Dec 2020 EIS	Upgrade of ECWMF atmospheric forcing to higher spatial and temporal resolution	EAS5	
04 May 2021 EIS	Major change of the modeling system due to inclusion of tides	EAS6	Time series availability: From 01/01/2019
29 November 2021	Time series replaced to use a corrected version of the SST satellite product (SST_MED_SST_L4_NRT_OBSERVATIONS_010_004)	EAS6	Time series availability: From 01/01/2019
14 December 2021	Use of Po river dicharge measurements instead of monthly climatologies	EAS6	Time series availability: From EIS
18 October 2022	Ingestion of Sentinel-6A SLA data	EAS6	Time series availability : From 18 October 2022
29 November 2022	Change in the modeling system due to an improved representation of tides Changes in data assimilation: use of a new Mean Dynamic Topography, assimilation of new satellites (HY-2A/B and S6) and filtered 7 km data for SLA assimilation	EAS7	Time series availability: From EIS 29 Nov 2022
30 November 2023 EIS	Updated modeling versions (NEMO v4.2 and WW3 v6.06) including OASIS coupler. Removed topographic wave drag. Use of new EOFs, and assimilaiton of in-situ data in the Atlantic box	EAS8	Time series available from EIS 30 November 2023

VI QUALITY CHANGES SINCE PREVIOUS VERSION

March 2019: From EAS4 to EAS5 system

The quality of the product is similar to the previous version.

Commented [EiC158]: ? Please fix.

Commented [ACG159R158]: It is specifically required by Mercator to keep the history of these section unchanged from previous versions. We can just remove the text in brachets.

December 2020: Use of higher spatial and temporal resolution ECMWF atmospheric forcing (more details in section 0).

The quality assessment of the daily analysis physical fields carried out using the higher resolution atmospheric forcing, has provided no significantly changes with respect to the previous system.

May 2021: Inclusion of tides: the tidal potential is calculated across the domain for the 8 constituents that are most important in the Mediterranean Sea: M2, S2, N2, K2, K1, O1, P1, and Q1. In addition, tidal forcing is applied along the lateral boundaries (Atlantic Ocean) by means of tidal elevations and tidal currents. Reduction of the NEMO time step from 240 to 120 s. Change of model bathymetry. Increased bottom friction at Gibraltar Strait. OceanVar scheme has been updated in order to account for the tidal signal in the along-track altimeter observations.

In the following figures we report the main quality changes between new system EAS6 with respect to the previous one EAS5 (**Figure 26** to **Figure 30**).

In all comparisons, we notice a slight decrease of both RMSD and bias in the new system EAS6 with respect to EAS5.

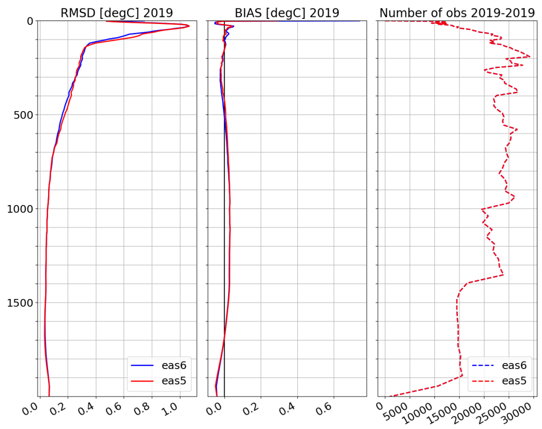

Figure 26*: Annual (2019) averaged profiles (0-2000m) of temperature RMSD and bias with respect to in-situ observations.*

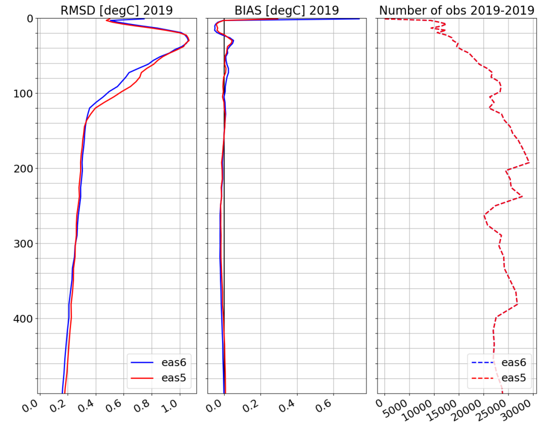

***Figure 27**: Annual (2019) averaged profiles (0-500m) of temperature RMSD and bias with respect to in-situ observations.*

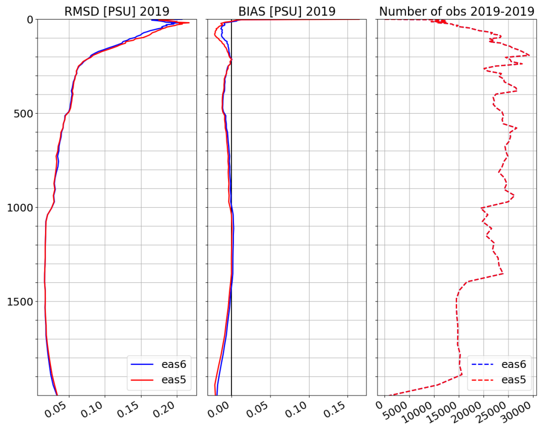

***Figure 28:** Annual (2019) averaged profiles (0-2000m) of salinity RMSD and bias with respect to in-situ observations.*

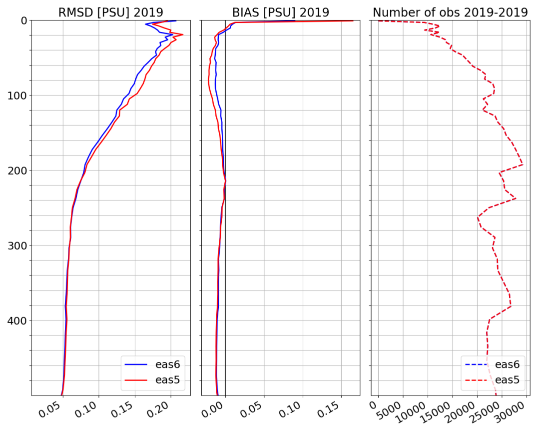

***Figure 29**: Annual (2019) averaged profiles (0-500m) of salinity RMSD and bias with respect to in-situ observations.*

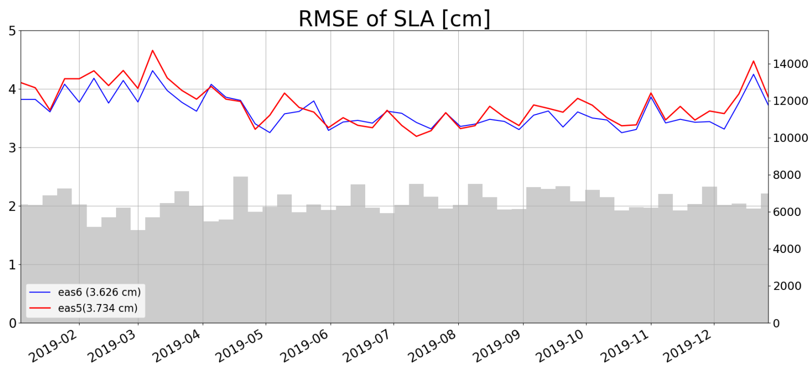

***Figure 30:** Time series of SLA RMSD with respect to satellite data (left axis). Grey bars represent the number of observations (right axis).*

November 2021: Use of a corrected version of the SST L4 satellite product (SST_MED_SST_L4_NRT_OBSERVATIONS_010_004) which was affected by an issue starting from April 2019 (designated as "corrupted data" in **Figure 31**) and was replaced with a new correct dataset.

An experiment has been done for the year 2019 to assess the impact of the correction in the satellite SST data on the MEDSEA_ANALYSISFORECAST_PHY_006_013 product. The results (**Figure 31**) show that the mean impact over the whole basin is negligible.

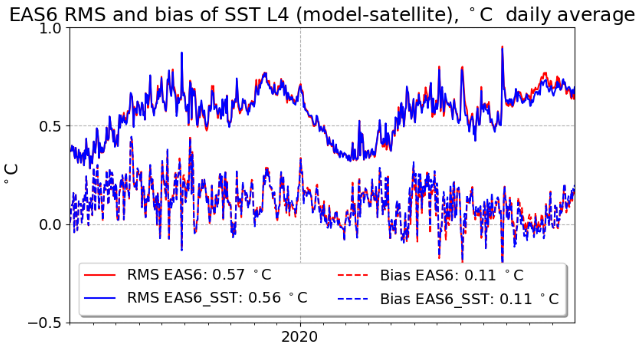

Figure 31: *Time series of SST RMSD and Bias of model outputs during year 2019 compared to SST L4 satellite data for an experiment which is relaxed using corrupted data (red lines) and the new experiment using corrected SST data (blue lines).*

Looking at the vertical distribution of RMSD (**Figure 32**) we find that RMSD decreases with increasing depth. Furthermore, there is a slight decrease in RMSD when corrected SST data are used to relax the model using non solar radiation.

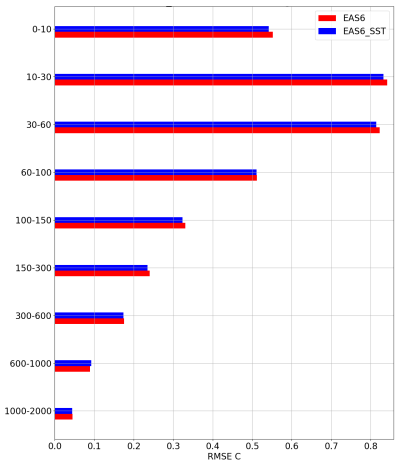

Figure 32: *Temperature RMSD in 9 vertical layers for model outputs with respect to in-situ observations. Model data relaxed to observations using corrupted data (red lines) and corrected SST data (blue lines).*

Commented [EiC160]: ? This needs to be explained. I have added a parenthesis to the first sentence. Please check.

Commented [ACG161R160]: As already explained in a previous answer, we cannot change these section that includes the history of changes (the text should be copied and pasted from the previous QUID versions). However, as explained in the text, the corrupted data are SST L4 products which were provided affected by an issue. I think we should let the production unit of these data to explain the issue.

Commented [EiC162R160]: OK

December 2021: Use of daily Po river discharge measurements distributed by ARPAE (Regional Agency for Prevention, Environment and Energy of Emilia-Romagna, Italy) and available from the website: https://simc.arpae.it/dext3r/. The Po river discharge is measured at the closing point of the drainage basin in Pontelagoscuro. The measured Po river runoff is in average lower than climatological values except for several periods where large discharges were **recorded (see** Figure 33**).**

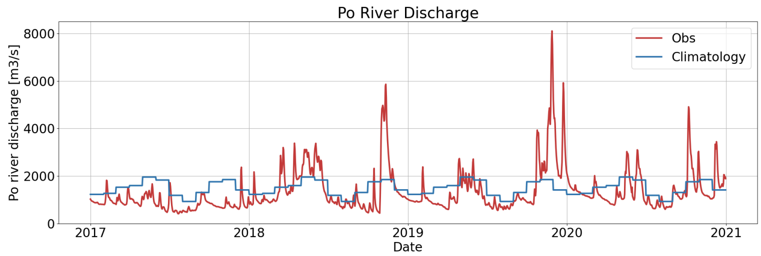

Figure 33: *Time series of Po river discharge: daily measurements (red) and monthly climatologies (blue).*

The model validation does not provide significant differences when considering yearly statistics in the basin and especially when data assimilation is included. Slight improvements have been achieved when comparing hindcast simulations during flooding events such as November 2018 and November-December 2019.

Figure 34 presents the RMSD (left) and Bias (right) of the model salinity evaluated in the North Adriatic Sea (region 11) during November 2018 showing that the higher frequency Po runoff produces some reduction of the salinity RMSD especially at surface layers.

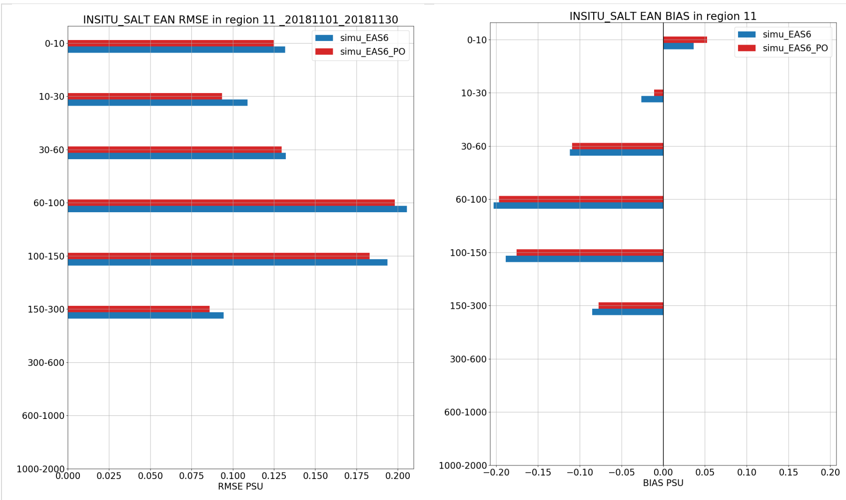

Figure 34*. Salinity RMSD (left) and Bias (right) evaluated comparing the daily mean model outputs of the EAS6 experiments forced with Po river climatologies (blue) and with daily observations (red) with respect to in-situ observations in November 2018 in the North Adriatic Sea (region 11).*

Similar results are achieved in the period November-December 2019 (period of large Po river discharge) and presented in **Figure 35**.

However, we should consider that a validation analysis in such a short period and in this small and shallow area is affected by the low availability of *in-situ* data.

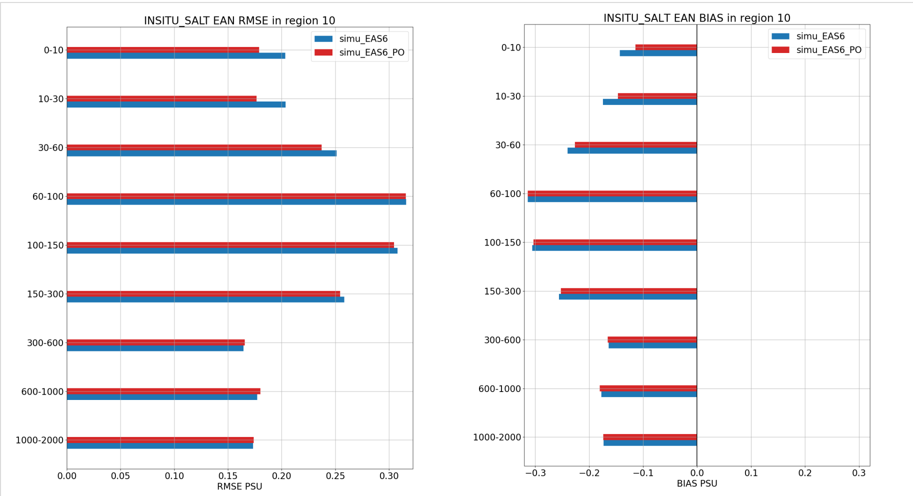

Figure 35. *Salinity RMSD (left) and Bias (right) evaluated comparing the daily mean model outputs of the EAS6 experiments forced with Po river climatologies (blue) and with daily observations (red) with respect to in-situ observations in November-December 2019 in the South Adriatic Sea (region 10).*

October 2022: Ingestion of Sentinel-6A (S6A) Sea Level Anomaly Satellite Altimeter Observations.

The impact of the assimilation of SLA data in the EAS6 system is investigated for the period 28 March - 28 June 2022 (in total three months). The operational system EAS6 has been run with and without the ingestion of SLA observations from S6A, namely EAS6_mfs1_s6a and EAS6_mfs1_nos6a, respectively.

In the following **Table 16** the mean RMS misfits (known also as innovations) calculated at observation time during the forward model integration (called first guess at appropriate time or FGAT) are provided for SLA, temperature (T) and salinity (S), at different model layers for temperature and salinity (1-15 m, 15-45 m, 45-135 m, 100-200 m, 200-400 m, 400-800 m).

	No Sentinel-6A (EAS6_mfs1_nos6a)		Sentinel-6A (EAS6_mfs1_s6a)	
SLA (cm)	3.1		3.0	
	T (°C)	**S (psu)**	**T (°C)**	**S (psu)**
1-15 m	0.65	0.18	0.67	0.17
15-45 m	0.63	0.16	0.61	0.15
45 - 135 m	0.30	0.12	0.30	0.12
100-200 m	0.22	0.083	0.23	0.085
200 - 400 m	0.20	0.048	0.20	0.049
400 - 800 m	0.11	0.028	0.12	0.029

***Table 16:** Time and space averaged RMS misfits of SLA with respect to all available satellites and of Temperature and Salinity along 6 vertical layers for the twin experiment with (EAS6_mfs1_s6a) and without (EAS6_mfs1_s6a) assimilation of Sentinel-6A SLA observations.*

Figure 36 presents the RMS of SLA misfits between 28 March 2022 and 28 June 2022 for the twin experiments showing a reduced misfit when S6A SLA observations are assimilated. The RMS misfits evolution of the experiments is close in the first days, since they start from the same initial conditions, while after 2 weeks the assimilation of S6A data produces a reduction of the RMS misfits from 3.1 cm to 3 cm. We note that the amount of data ingested has increased by approximately 20% with the introduction of S6A.

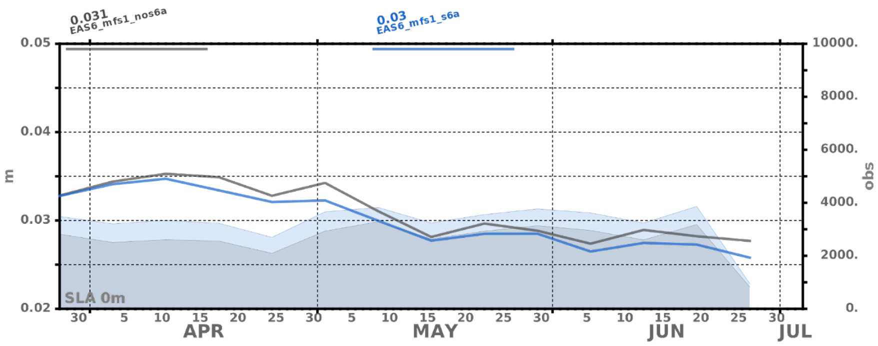

***Figure 36**: Weekly time series of RMS of SLA misfits between 28 March 2022 and 28 June 2022. The experiment EAS6_mfs1_nos6a without Sentinel-6A assimilation (grey line) and EAS6_mfs1_s6a with Sentinel-6A assimilation (blue) are shown. The time averaged RMS of SLA misfits (m) is printed on the legend. The number of assimilated observations (right y-axis) is shaded with the respective colour.*

The analysis shows that the information incorporated with the new dataset is in agreement with the already existing ones and does not degrade the system. There are some improvements at the sampling locations of other satellites as demonstrated by the misfit statistics. The temperature and salinity estimates are also evaluated since they are directly updated by SLA assimilation. First findings reveal differences in temperature and salinity with close RMS misfits estimates.

November 2022: The representation of tides has been improved including a Topographic Wave Drag parameterization and a correction to the Bottom Friction coefficient. In **Table 17** and **Table 18** the improvements on the model output, with respect to the previous model version, are shown in terms of salinity and temperature misfits over the five-years period 2017-2021. For what concerns the temperature, the comparison does not provide significant differences while, for salinity, a slight improvement can be noticed.

System version	S [PSU] 8 m	S [PSU] 30 m	S [PSU] 150 m	S [PSU] 300 m	S [PSU] 600 m
EAS7	0.17±0.03	0.16±0.04	0.09±0.02	0.047±0.008	0.029±0.005
EAS6	0.17±0.03	0.17±0.03	0.10±0.02	0.048±0.004	0.029±0.005

***Table 17**: Comparison between salinity RMSD misfits obtained from EAS7 and EAS6 system versions with respect to in-situ observations. The values have been computed on the period 2017-2021*

System version	T [°C] 8 m	T [°C] 30 m	T [°C] 150 m	T [°C] 300 m	T [°C] 600 m
EAS7	0.56±0.20	0.78±0.42	0.25±0.06	0.18±0.04	0.11±0.02
EAS6	0.54±0.20	0.78±0.44	0.26±0.06	0.19±0.04	0.11±0.02

***Table 18**: Comparison between temperature RMSD misfits obtained from EAS7 and EAS6 system versions with respect to in-situ observations. The values have been computed on the period 2017-2021*

Moreover Gibraltar and Messina Straits parameterizations have been modified. In particular the increased bottom friction in the area outside Gibraltar strait has been removed while the lateral friction inside the strait has been doubled. The gain due to this modification, that contributes to the improvements shown in Table 17, concerns the salinity.

For what concerns the Messina strait, the area of enhanced lateral friction has been modified. Comparing the tidal phase obtained from harmonic analysis applied to the EAS6 and EAS7 system versions, clear improvements appear. See Figure 37 where the comparison between the scatter plots for amplitude and phase of the main tidal component, namely M2, are compared between the two system version. The points concerning the Messina area are the orange ones. General improvements in the harmonic analysis results can be stated also looking at the Slope and R2 parameters obtained from the linear regression given in the legends of the plots in Figure 37.

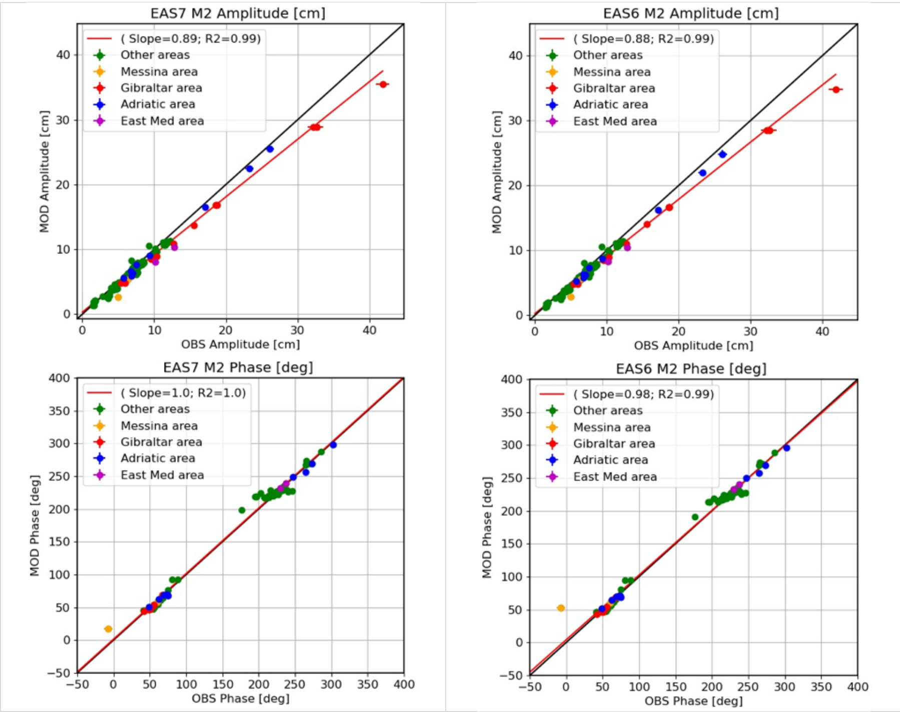

***Figure 37**: Comparison between the scatter plots of M2 tidal component amplitude and phase with respect to tide-gauge data obtained from the harmonic analysis applied to the EAS6 and EAS7 versions.*

Finally the use of a new MDT, filtered 7 km data and new satellite data (HY-2A/B and S6) for SLA assimilation have shown to provide a major improvement in RMSD of SLA, see **Figure 38** where the comparison with respect to the previous system is depicted in terms of SLA RMSD of misfits obtained on a five-year period 2017-2021. The mean value over the whole period moves from 3.36±0.24 cm to 3.04±0.24 cm.

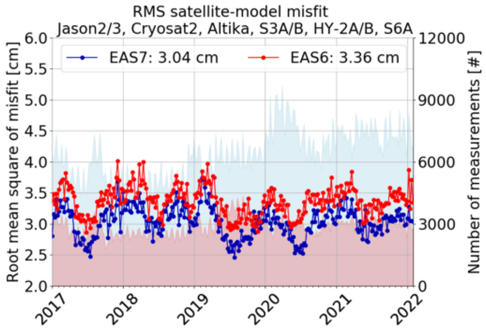

Figure 38: *Comparison between SLA RMSD misfits obtained from EAS7 and EAS6 system versions with respect to satellite data. The values have been computed on the period 2017-2021*

November 2023 From EAS7 to EAS8. In **Table 19** and **Table 18** the improvements on the model outputs, with respect to the previous model version, are shown in terms of salinity and temperature RMSD (EANs) respectively over the five-years period 2017-2021. For both temperature and salinity the EAS8 RMSD is lower with respect to the one of the previous version EAS7.

System version	S [PSU] 0-10 m	S [PSU] 10-30 m	S [PSU] 30-60 m	S [PSU] 60-100 m	S [PSU] 100-150 m	S [PSU] 150-300 m	S [PSU] 300-600 m	S [PSU] 600-1000 m	S [PSU] 1000-2000 m
EAS7	0.21	0.22	0.19	0.15	0.12	0.07	0.04	0.03	0.02
EAS8	0.19	0.19	0.17	0.13	0.11	0.06	0.04	0.02	0.01

Table 19: *Comparison between salinity RMSD (EANs) obtained from EAS8 and EAS7 system versions with respect to in-situ observations. The values have been computed on the period 2017-2021.*

System version	T [°C] 0-10 m	T [°C] 10-30 m	T [°C] 30-60 m	T [°C] 60-100 m	T [°C] 100-150 m	T [°C] 150-300 m	T [°C] 300-600 m	T [°C] 600-1000 m	T [°C] 1000-2000 m
EAS7	0.64	0.96	0.90	0.55	0.35	0.24	0.19	0.11	0.05
EAS8	0.57	0.86	0.80	0.48	0.31	0.22	0.16	0.09	0.04

Table 20: *Comparison between temperature RMSD (EANs) obtained from EAS8 and EAS7 system versions with respect to in-situ observations. The values have been computed on the period 2017-2021.*

In **Figure 39** the time series of weekly mean model SLA RMSD with respect to altimeter data is provided showing a reduction of about 10% in the period 2017-2021 .

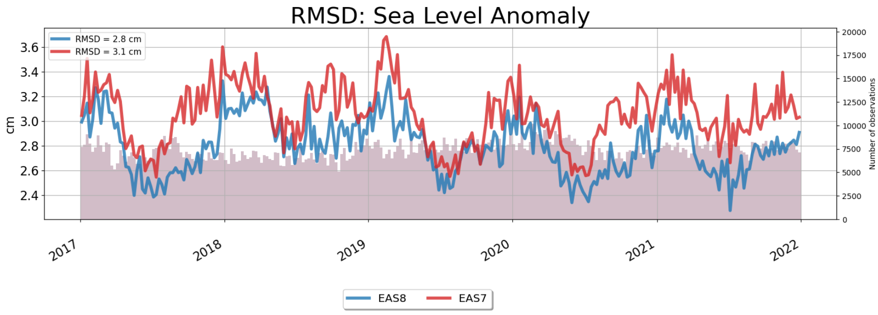

Figure 39: *Comparison between SLA RMSD obtained from EAS7 (red line) and EAS8 (blue line) system versions with respect to satellite data. The values have been computed on the period 2017-2021.*

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