



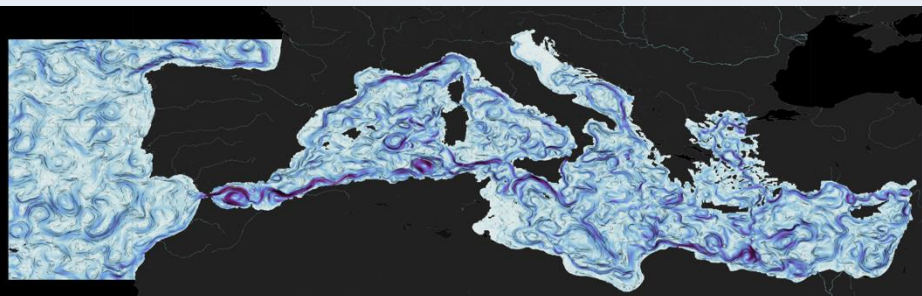
Regional Operational Forecasting Systems at CMCC

Emanuela Clementi
& Regional Ocean Forecasting Systems Division @CMCC

www.cmcc.it



Regional Ocean Forecasting @ CMCC – Major Assets



MyOcean EU Projects

Pre operational phase

2009-2015

Start of Copernicus Marine (CMEMS)

First version of MedFS operational system within CMEMS

2015
EAS1

Major System improvements

- Updated models version
- MedFS from 1/16° to 1/24°
- ECMWF from 1/8° to 1/10°
 - From 7 to 39 rivers

2015-2020
EAS1-EAS5

Major System improvements

Added tides: 8 components

2021
EAS6

Major System improvements

- Updated models version
 - New rivers
- New observations

2022 – 2026
EAS7-EAS10

Major System improvements

- Updated models version
- BSFS from 3km to 2.5km
- BSFS from 31 to 121 levels
- ECMWF from 1/8° to 1/10°

2016

Start of Copernicus Marine (CMEMS)

First version of BSFS operational system within CMEMS

2016-2021

Major System improvements

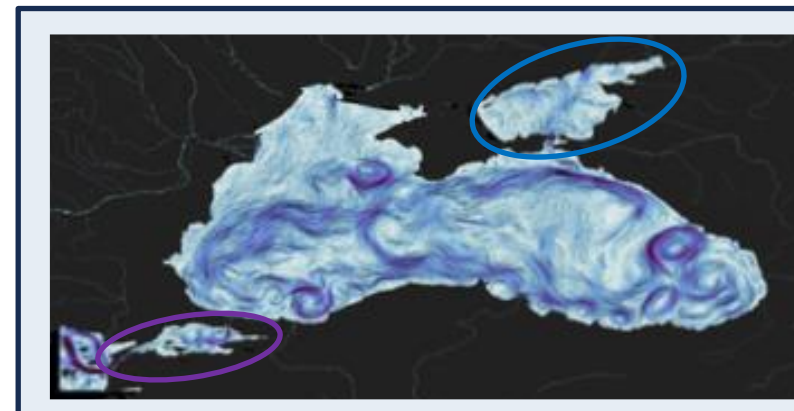
Added Marma Sea @ 500m resolution

2023

Major System improvements

Added Azov Sea

2024-2026



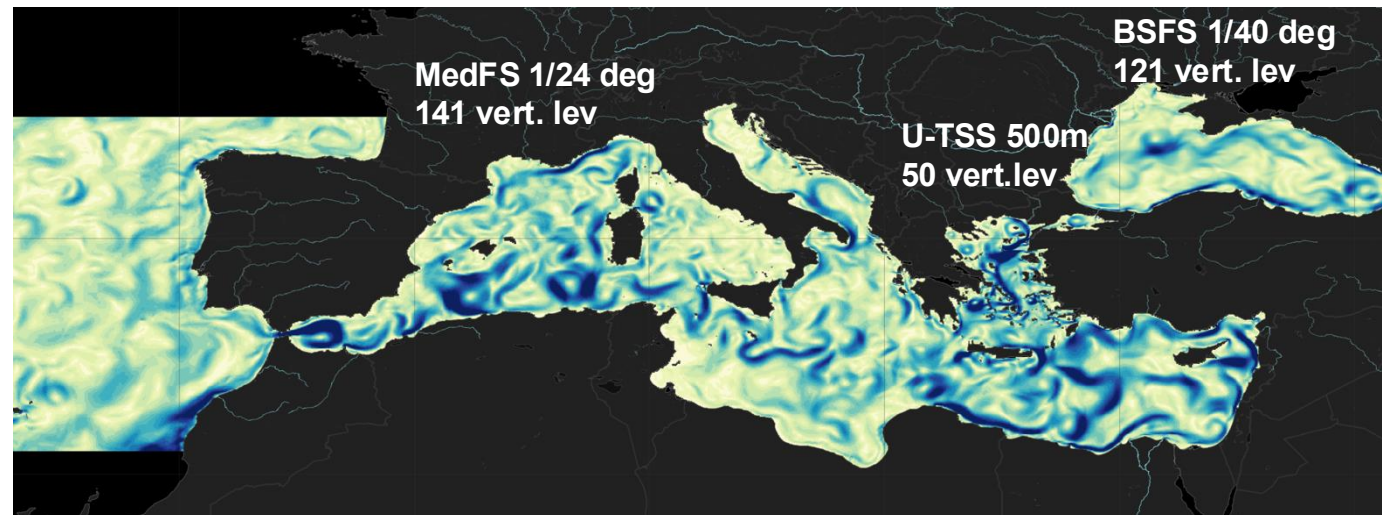
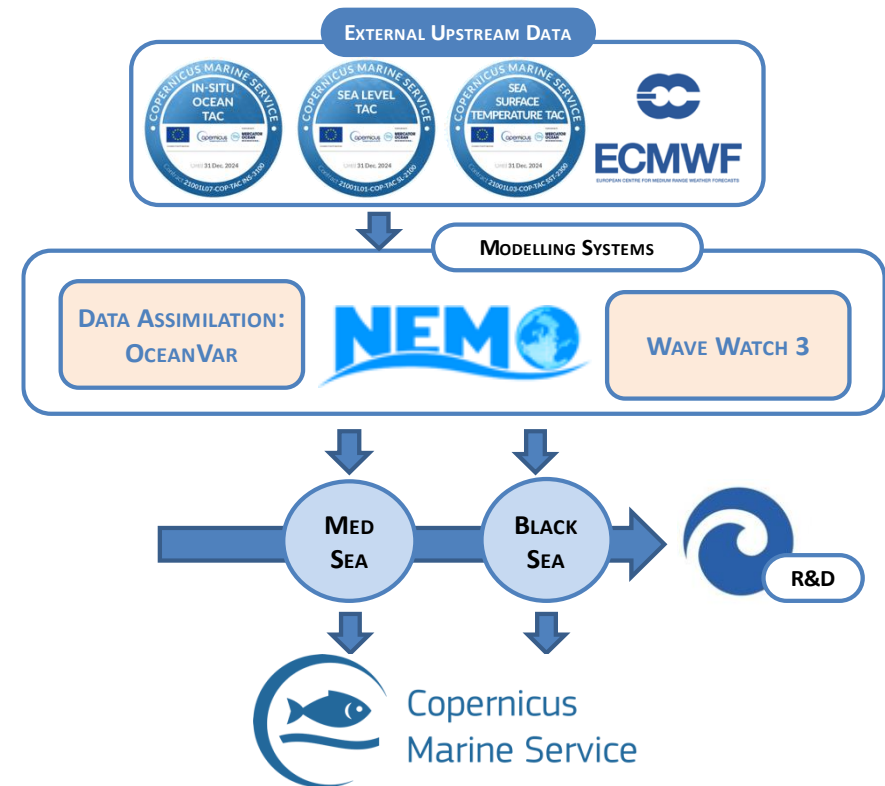
Regional Ocean Forecasting @ CMCC – Major Assets

Mediterranean and Black Sea operational forecasting systems

CMCC operationally produces analysis and forecast and reanalysis for the Mediterranean and Black Seas in the Copernicus Marine Service framework

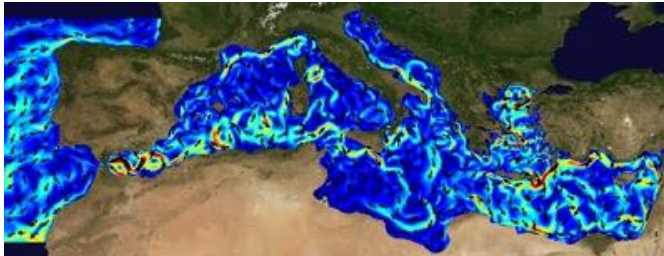
The forecast systems major components:

- ocean circulation model **NEMO**
- wave model **WaveWatch3**
- 3D variational data assimilation **OceanVar**



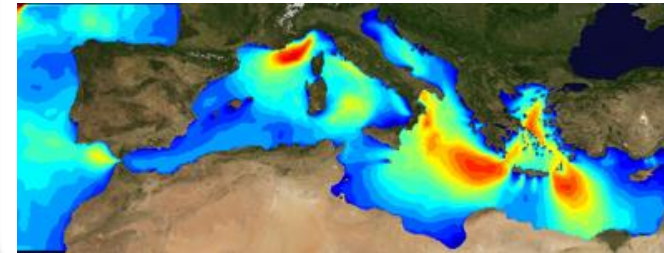
Mediterranean Sea Forecasting System Description

Ocean General Circulation Model
(OGCM) based on **NEMOv4.2** (tides)

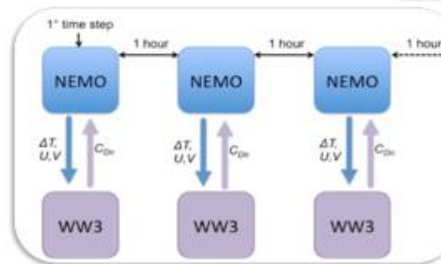


Hor. Res. = $1/24^\circ$ (~4 km)
Vert. Res. = 141 z* vertical levels
with partial cells

Wave model
WaveWatch-III (**WW3v6.07**)



2-way
hourly
coupling
OASIS



Hor. Res. = $1/24^\circ$ (~4 km)
Spectral discretization:
* 30 freq. bins (0.05-0.79 Hz)
* 24 directional bins

The two-way coupling consists of inputting:
Currents (for wave refraction) and **air-sea temperature difference** (for wind speed correction) to the wave model
and
providing the **neutral surface drag coefficient** from waves used to compute the wind stress in NEMO

ECMWF 1/10° atmospheric fields (from Italian Air Force):

- MSLP, cloud cover, 2m relative humidity
- 2m T, 10m Wind, Precipitations

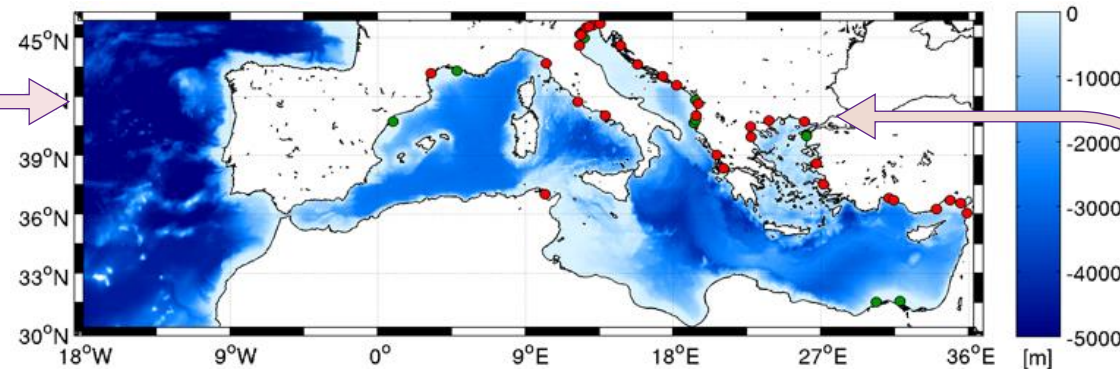
Temporal resolution:

Forecasts: 1hr – 3hrs – 6 hrs

Analysis: 6 hours time resolution

Land river runoff:

Surface boundary condition for **39** major rivers from EFASv5 dataset



Lateral Boundary conditions in the Atlantic:

Daily NRT analyses and forecasts from Copernicus Global Ocean Forecasting System (GLO-MFC) @ 1/12° horizontal resolution, 50 vertical levels

Lateral Boundary conditions in the Dardanelles Strait:

Unstructured Turkish Straits System (U-TSS)

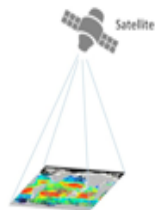
Model solutions are corrected by using observations

Satellites and insitu observations are jointly assimilated using a **3D variational scheme (OceanVar)** adapted to the oceanic assimilation problem with a daily cycle

The assimilated data are:

Along track Sea Level Anomaly from CMEMS SL-TAC

- Jason 3
- Cryosat2
- Saral/AltiKa
- HY-2B
- Sentinel3A/B-6

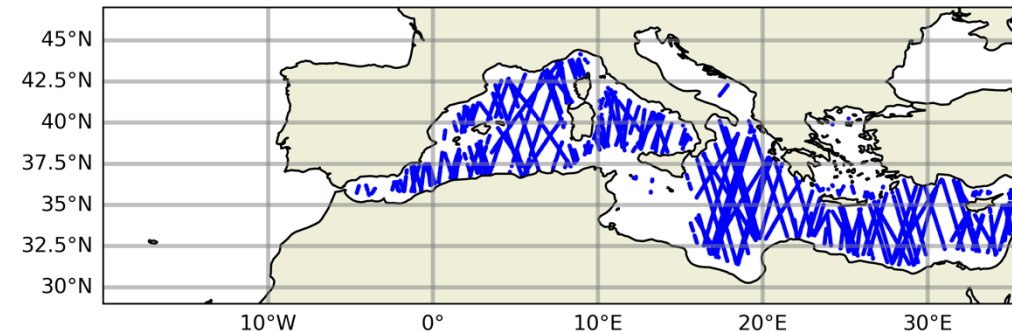
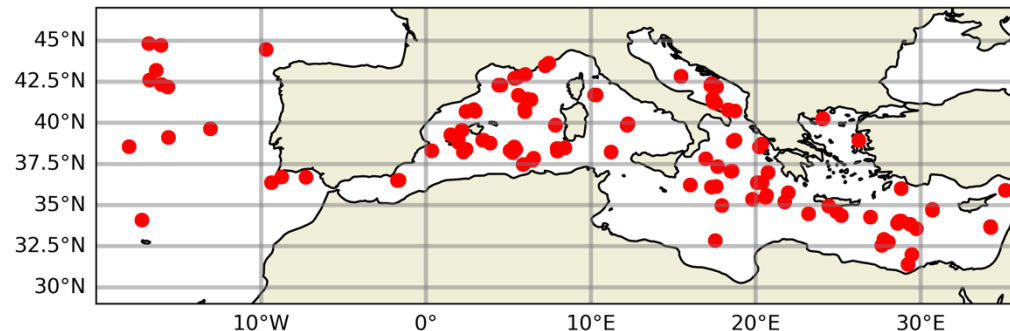


Vertical profiles of Temperature and Salinity from CMEMS InSitu TAC:

Argo XBT. Gliders



Non-solar heat flux correction is achieved through satellite SST nudging



of assim. obs. in 1 week

1. New Data Assimilation code: OceanVar2.0

OceanVar: first introduced by Dobricic and Pinardi (2008) based on a 3DVAR method

OceanVar2.0:

Oddo et al., 2026: Implementation and evaluation of sea level operators in OceanVar2.0: an open-source oceanographic three-dimensional variational data assimilation system. Geoscientific Model Development, doi: 10.5194/gmd-19-423-2026)

CMCC OceanVar2.0 Webpage:

<https://www.cmcc.it/models/oceanvar>

<https://github.com/CMCC-Foundation/OceanVar2>

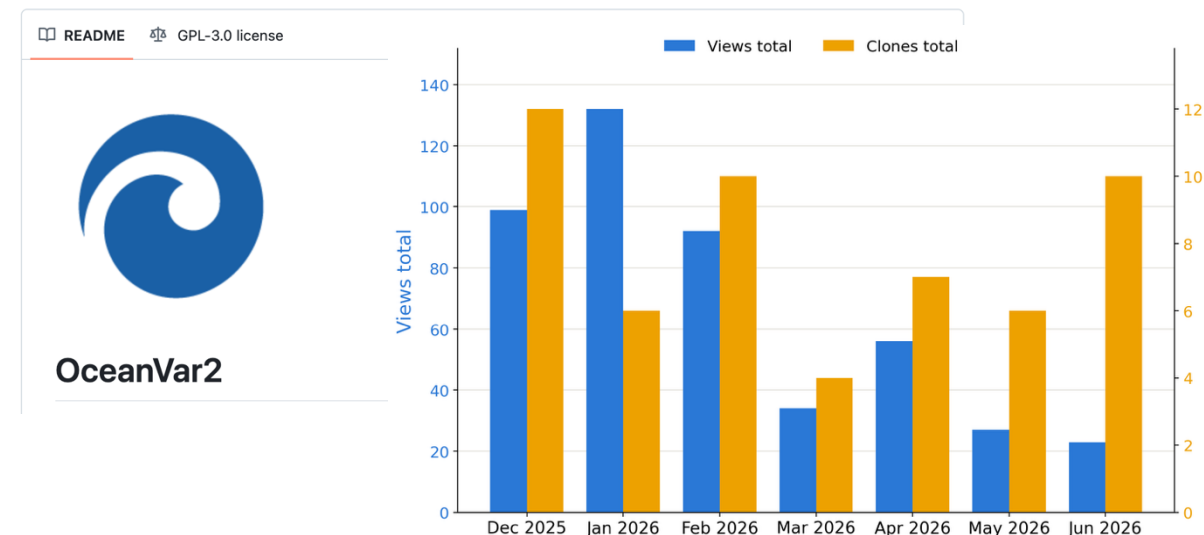
user guide

PDF User guide can be downloaded [here](#). Doxygen documentation can be generated using the [Doxyfile](#)

Test Case

To help users become familiar with the code, a test-case is also provided [here](#)

main	2 Branches	1 Tag	Go to file	Code
adanimario Add links to the references in the README.md file f526034 · last year 8 Commits				
bin	Add OceanVar2 code	last year		
doc	Add webpage figure	last year		
namelist	Add OceanVar2 code	last year		
prep	Add OceanVar2 code	last year		
src	Add OceanVar2 code	last year		
test_case	Add OceanVar2 code	last year		
test_suite	Add OceanVar2 code	last year		
LICENSE	Add OceanVar2 code	last year		
README.md	Add links to the references in the README.md file	last year		



1. New Data Assimilation code: OceanVar2.0

OLD:

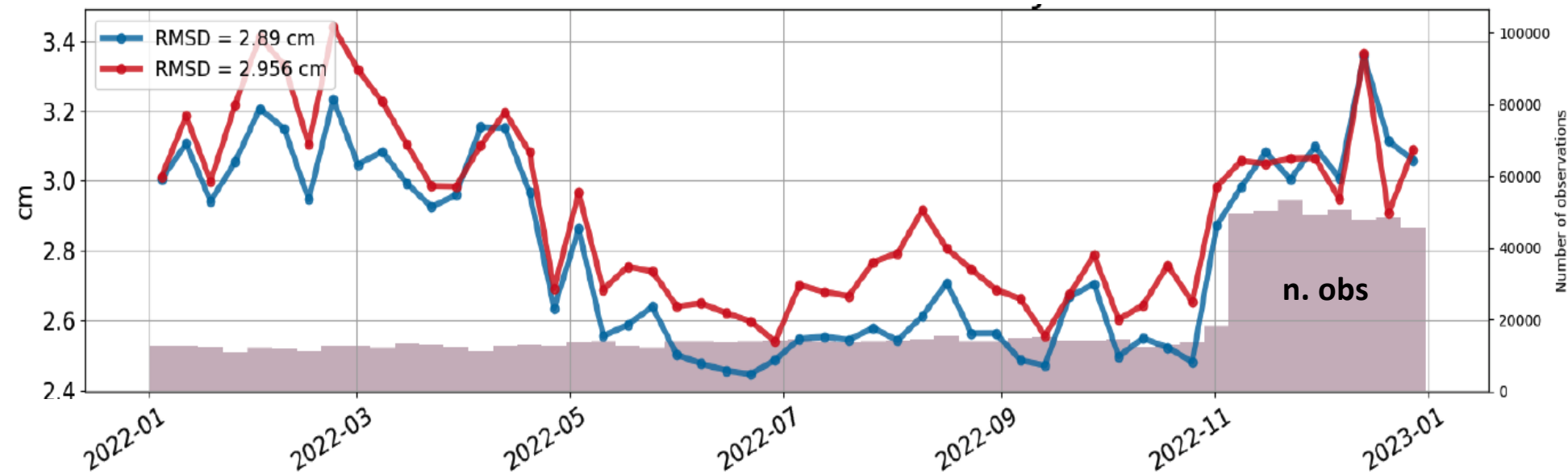
Dynamic height operator
Assimilation below 1000m

NEW:

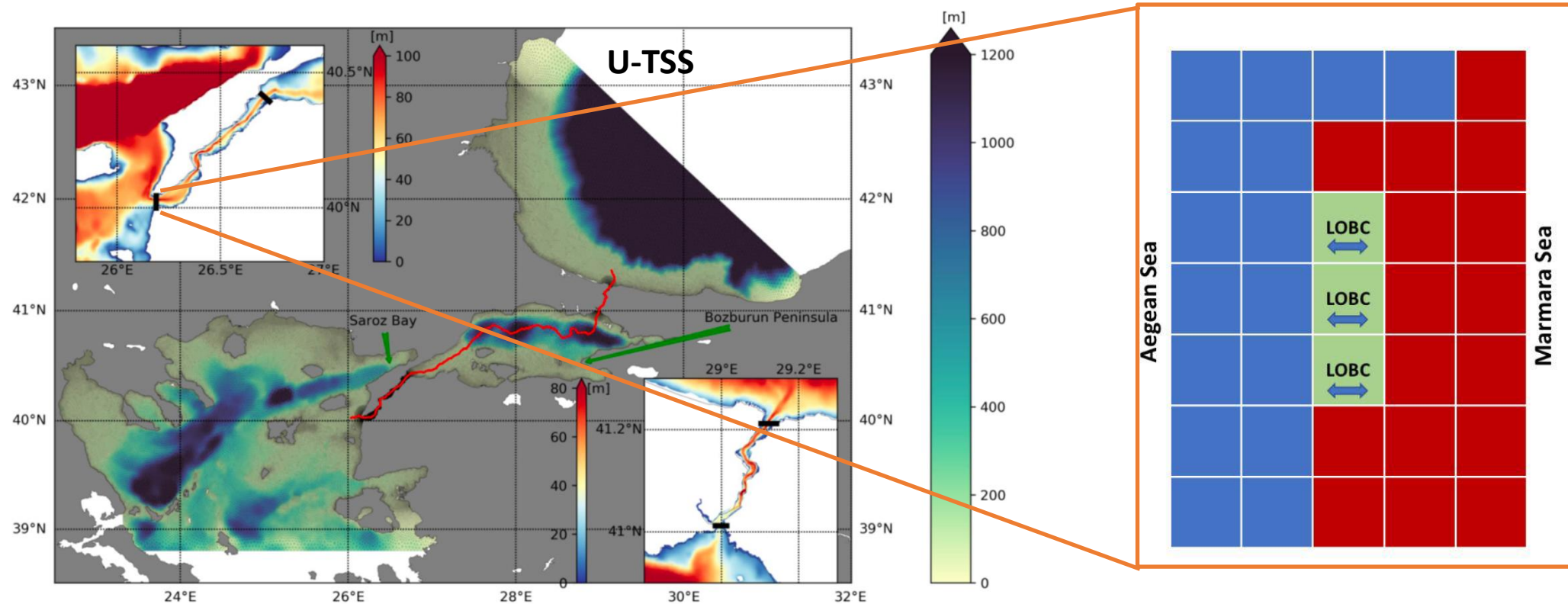
Barotropic model operator
Assimilation below 150m

- Increased n. of assimilated observations (closer to coastal areas)
- Improved skill

Mediterranean Sea SLA RMSD



2. New Lateral Open Boundary Conditions at Dardanelles Strait



Open Boundary conditions from U-TSS: Increased connection with the Black Sea Forecasting system

2D: Flather

3D velocities: Flow Relaxation Scheme

3D tracers: Specified

2. New Lateral Open Boundary Conditions at Dardanelles Strait

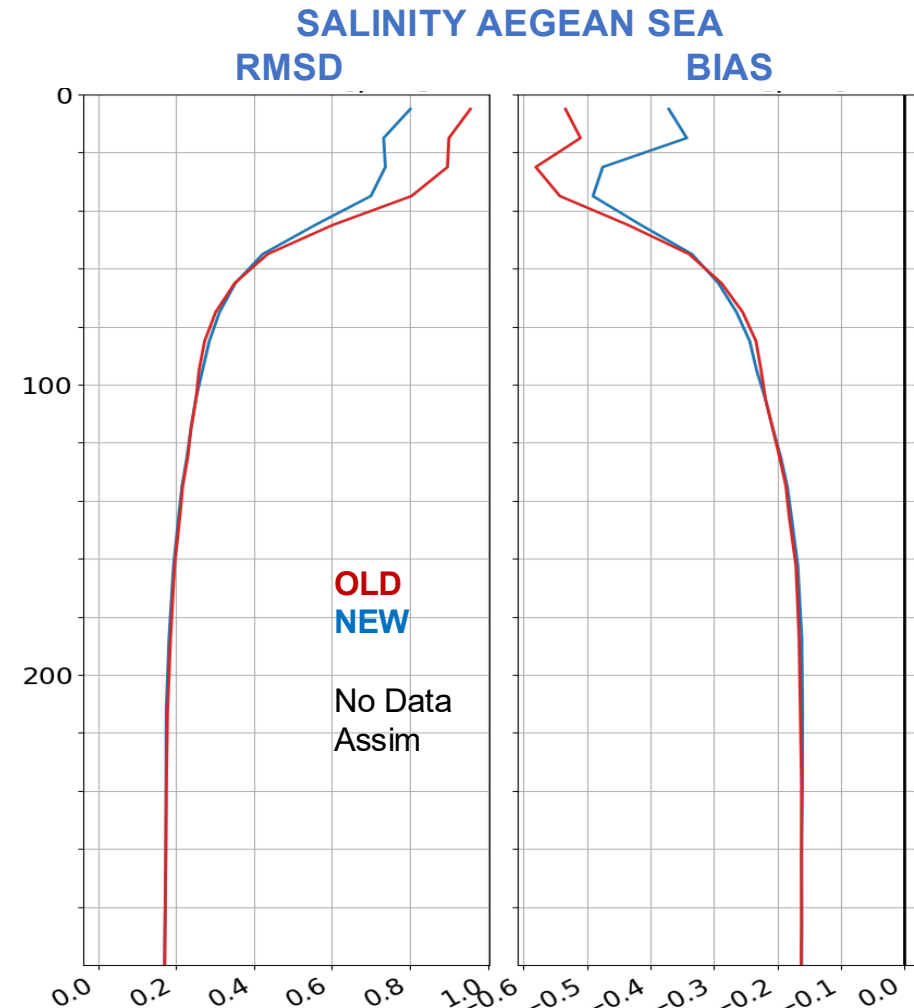
OLD:

LOBC from Maderich box model +
CMEMS Global model

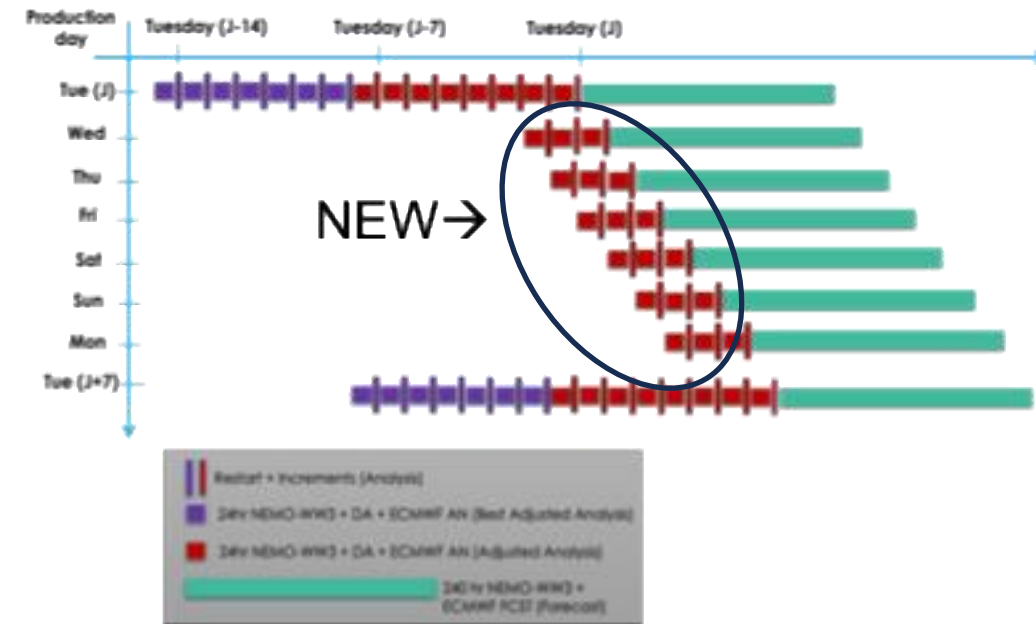
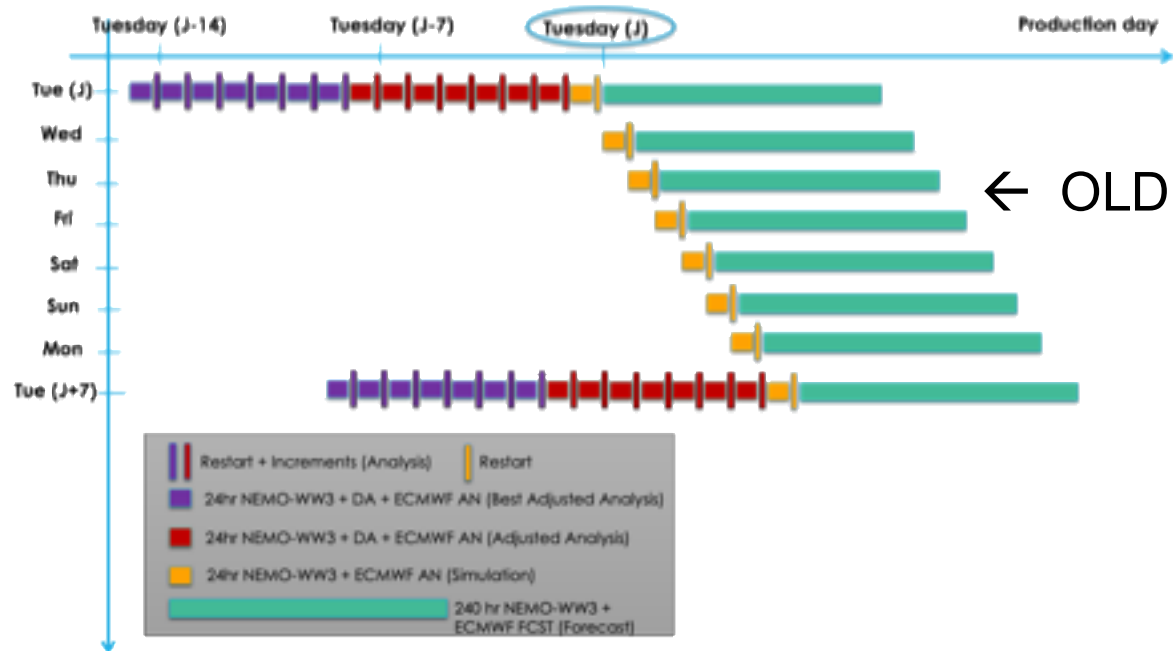
NEW:

LOBC from Maderich box model +
U-TSS model

- Increased connections with the
CMEMS Black Sea systems
- Improved salinity skill in the
Aegean Sea



3. Updated Operational Chain

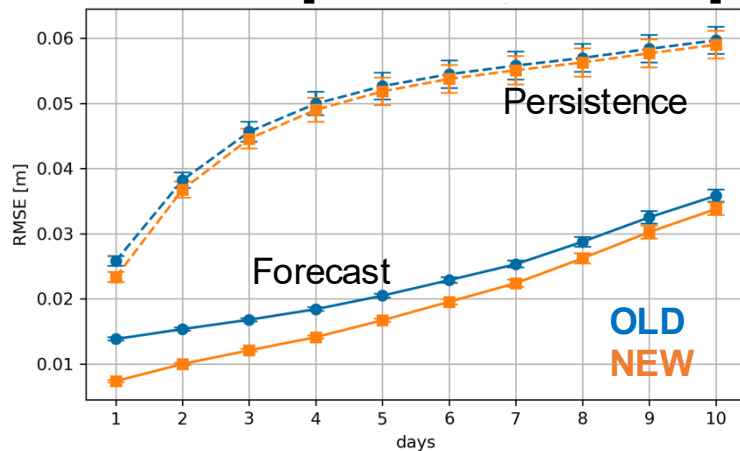


MedFS Upgrades @ November 2025

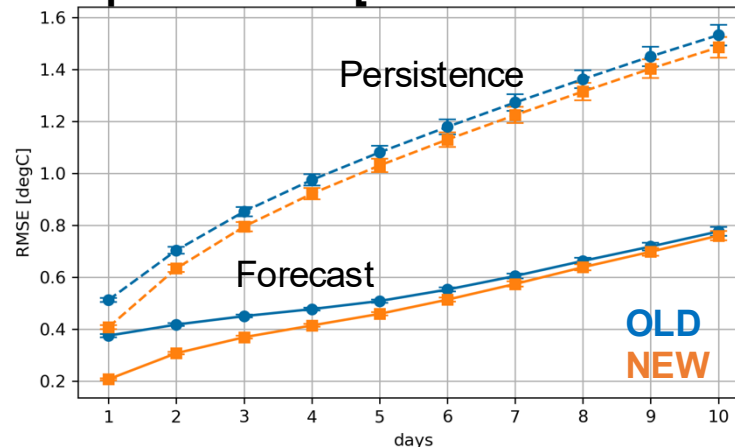


3. Updated Operational Chain

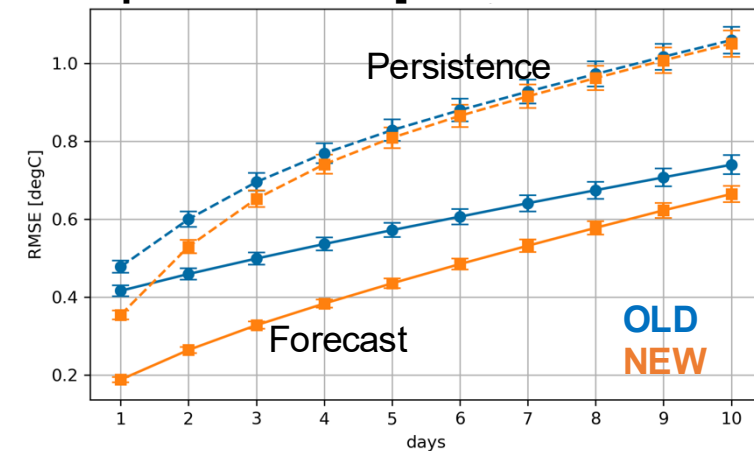
SSH RMSD [20250501-20250831]



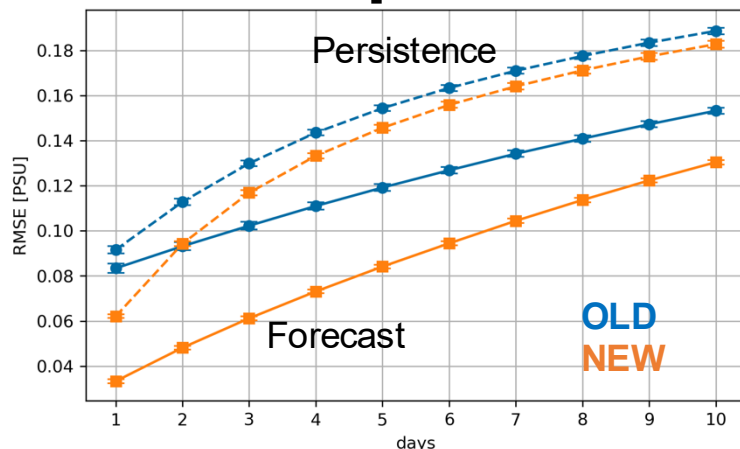
Temp 0m RMSD [20250501-20250831]



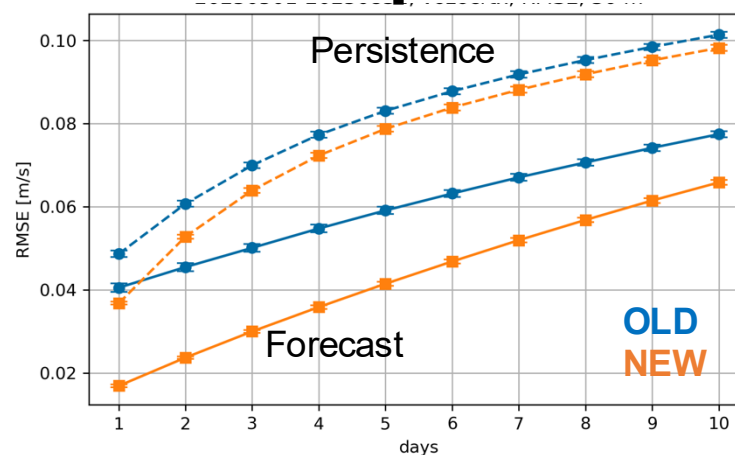
Temp 30m RMSD [20250501-20250831]



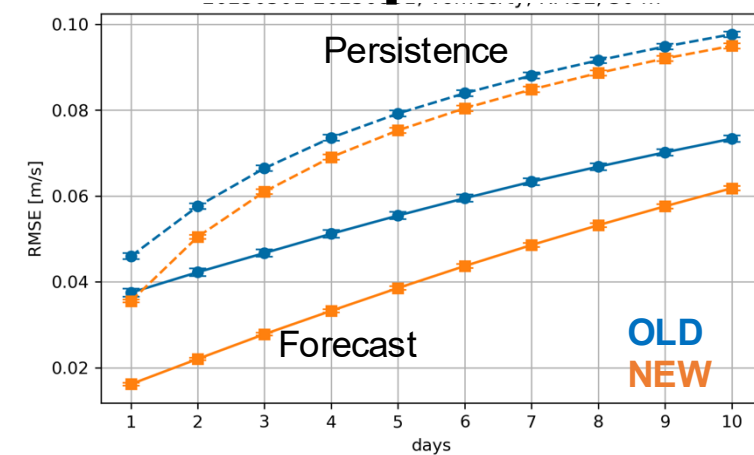
Sal 30m RMSD [20250501-20250831]



U.Vel 30m RMSD [20250501-20250831]



V.Vel 30m RMSD [20250501-20250831]



Mediterranean Sea Forecasting System Operational Validation

1. CMEMS PQD: <https://marine.copernicus.eu/user-corner/>
2. CMCC Website: <https://medfs.cmcc.it/>

CLASS4 T, S, SLA: quasi-independent validation wrt assimilated data. Time series of RMS misfits + Hovmoller + bulletin of assimilated and rejected data → [CMCC Website](#)

CLASS2 T, S, SST, SSH: independent validation wrt fixed moorings. Time series + RMSD & BIAS → [CMCC Website](#)

CLASS4 T, S, SST, SLA: quasi-independent validation wrt CMEMS INSITU & Satellite data. Time series of RMSD and BIAS of analysis and forecasts → [Copernicus Marine PQD](#)

CLASS2 SST: Independent validation wrt CMEMS Moorings → [Copernicus Marine PQD](#)

CLASS1/2/4 T, S, SST, SLA, U, V, MLD, Tb: Pre-operational Qualification wrt INSITU, Satellite & Literature data → [Copernicus Marine Quality Information Document](#)

Every
Week

Every
month

Every year /
For each new NRT version

Mediterranean Sea Forecasting System Operational Validation

1. CMEMS PQD: <https://marine.copernicus.eu/user-corner/>
2. CMCC Website: <https://medfs.cmcc.it/>

CLASS4 & CLASS2 & CMEMS PQD: monitoring over the Med Sea + 16 regions and along 9 vertical layers

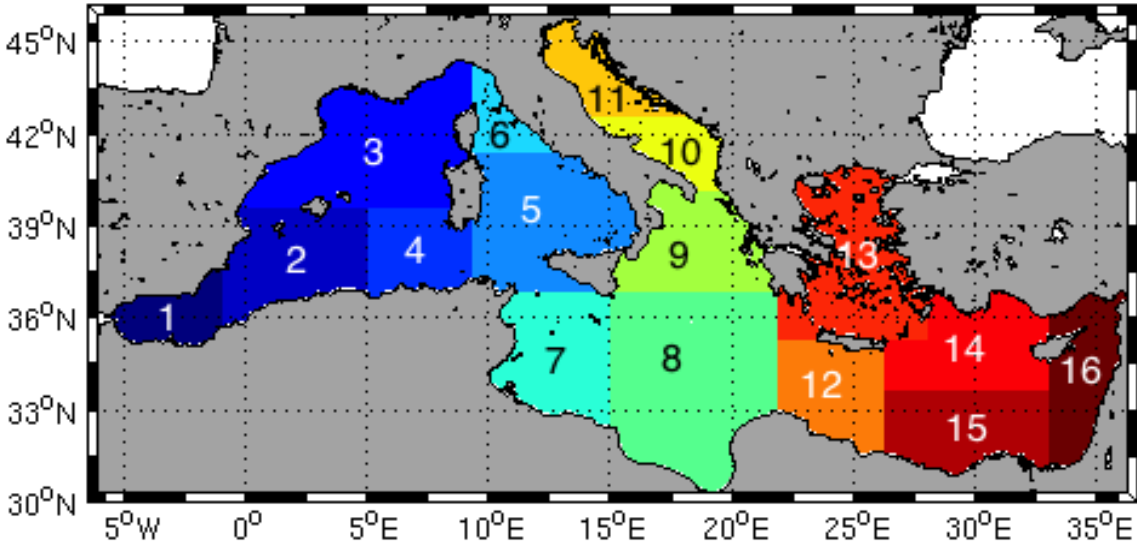
Monthly update

CLASS4 - EANs

SST (vs Sat L4 and L3S)
SSH
3D Temperature
3D Salinity

CLASS2

Surface: temperature, salinity, sea level



Layers & depth [m]	
1	0-10
2	10-30
3	30-60
4	60-100
5	100-150
6	150-300
7	300-600
8	600-1000
9	1000-2000

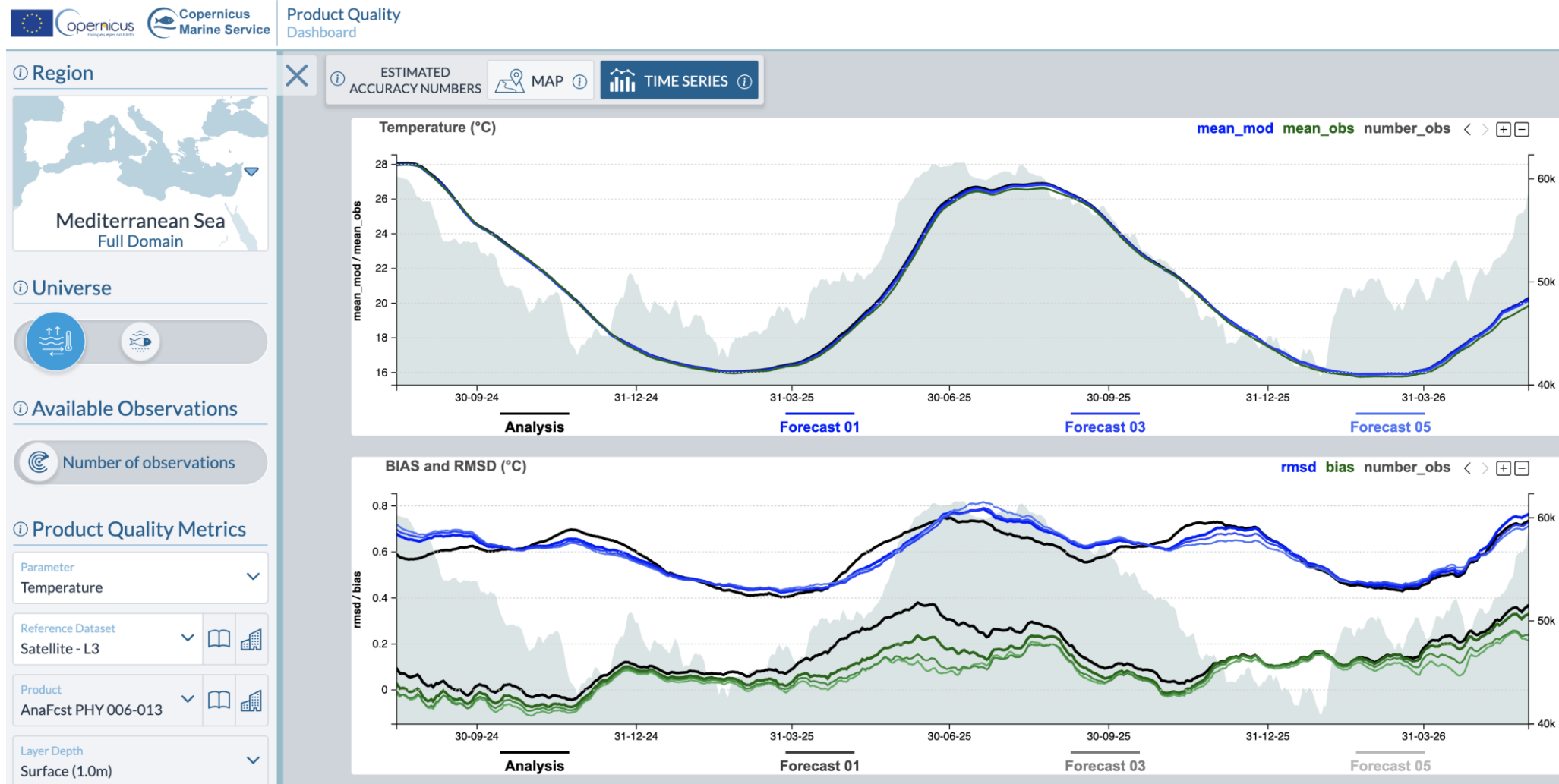
Temp. Freq.	Analysis	Forecast 01	Forecast 03	Forecast 05
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PQ Metrics	Mean	Bias	RMSD
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Copernicus Marine PQ Dashboard



CMEMS PQ Dashboard – CLASS4



Temperature
Whole Med Sea

Model @ surface
VS
Satellite SST L3

Copernicus Marine PQ Dashboard



CMEMS PQ Dashboard – CLASS4

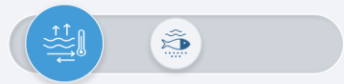


Product Quality
Dashboard

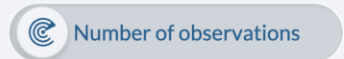
Region



Universe



Available Observations



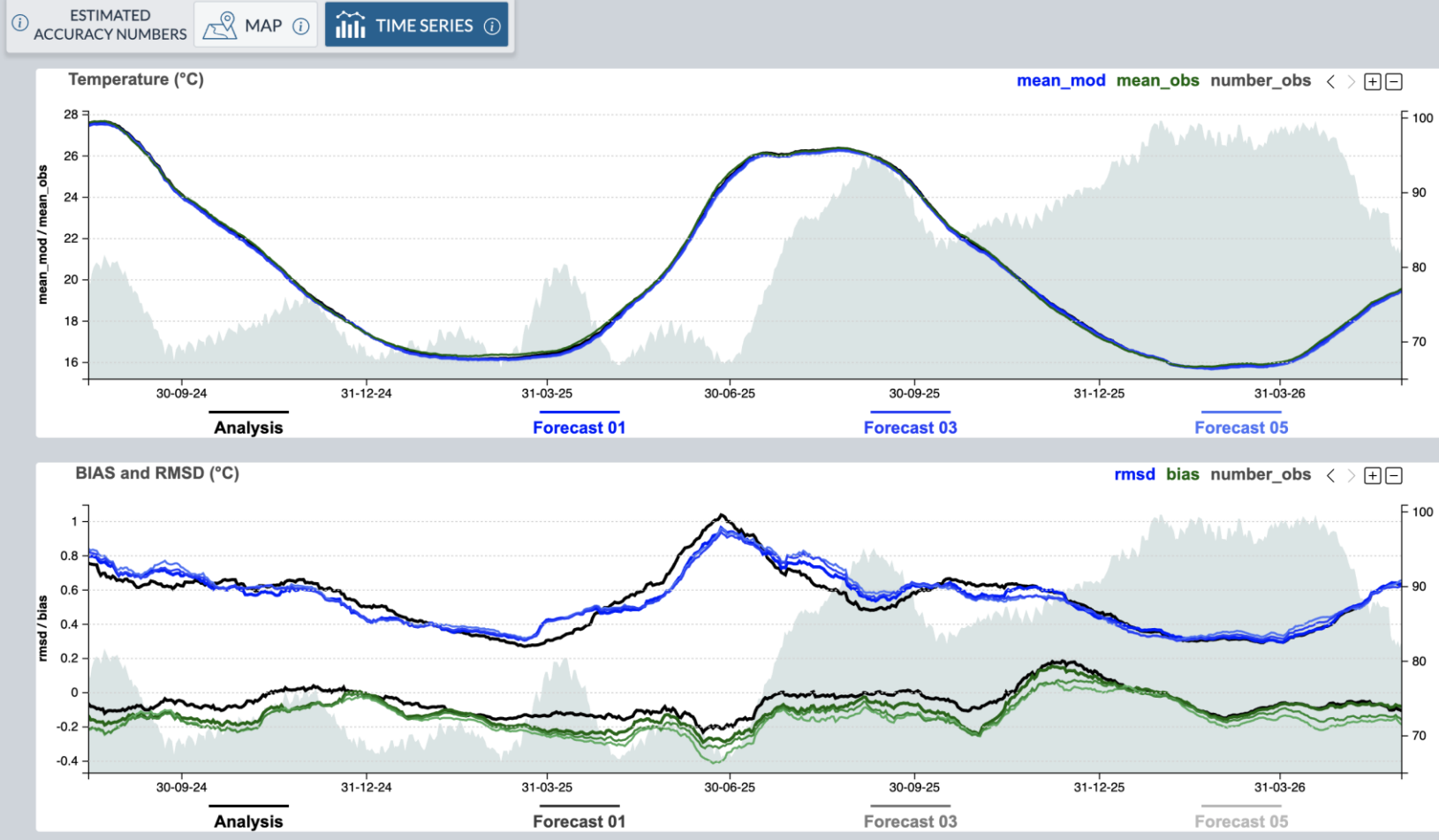
Product Quality Metrics

Parameter
Temperature

Reference Dataset
In Situ - MultiObs

Product
AnaFcast PHY 006-013

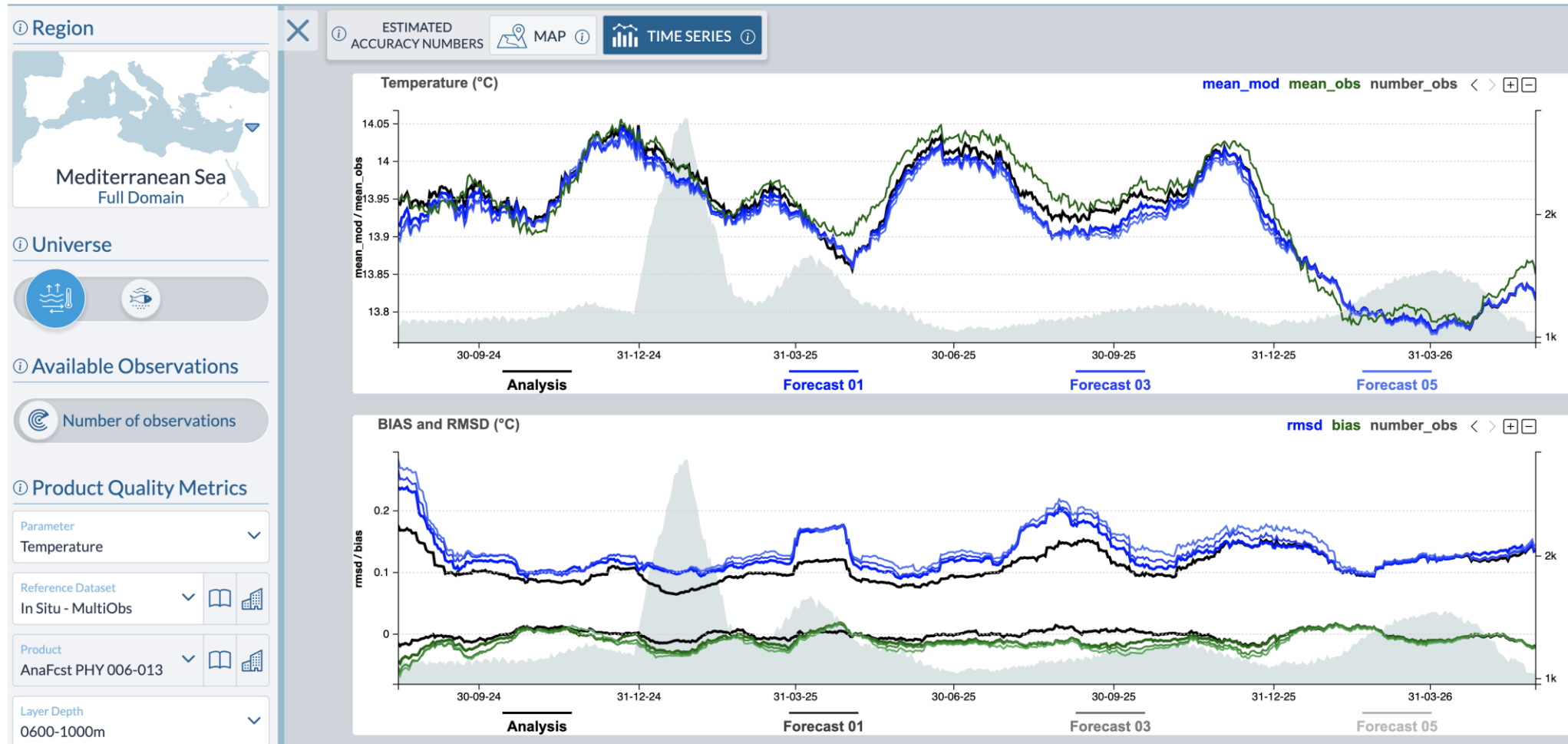
Layer Depth
0000-0010m



Temperature
Whole Med Sea

Model @ 0-10m
VS
in-situ

CMEMS PQ Dashboard – CLASS4



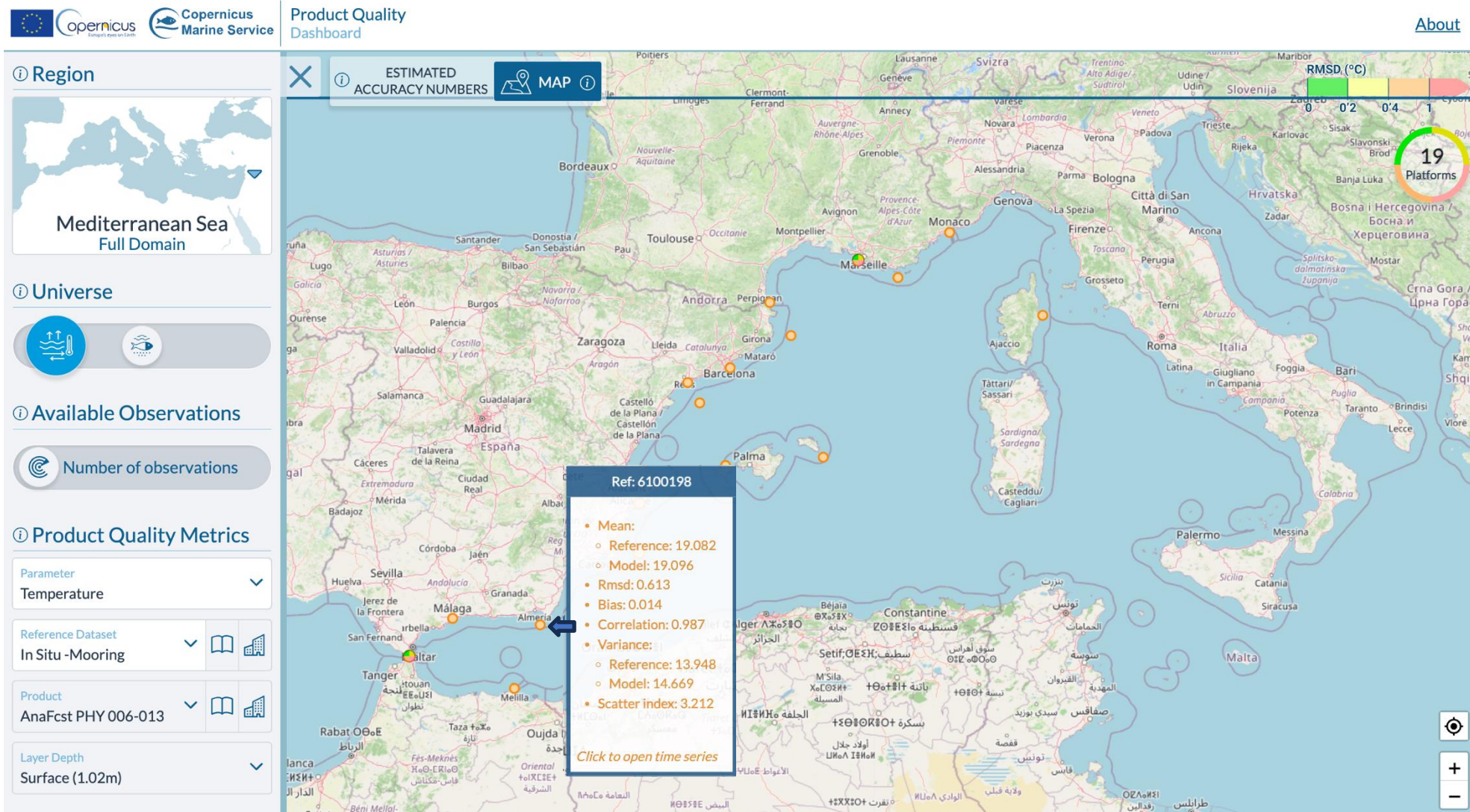
Temperature
Whole Med Sea

Model @ 60-100m
VS
in-situ

Copernicus Marine PQ Dashboard



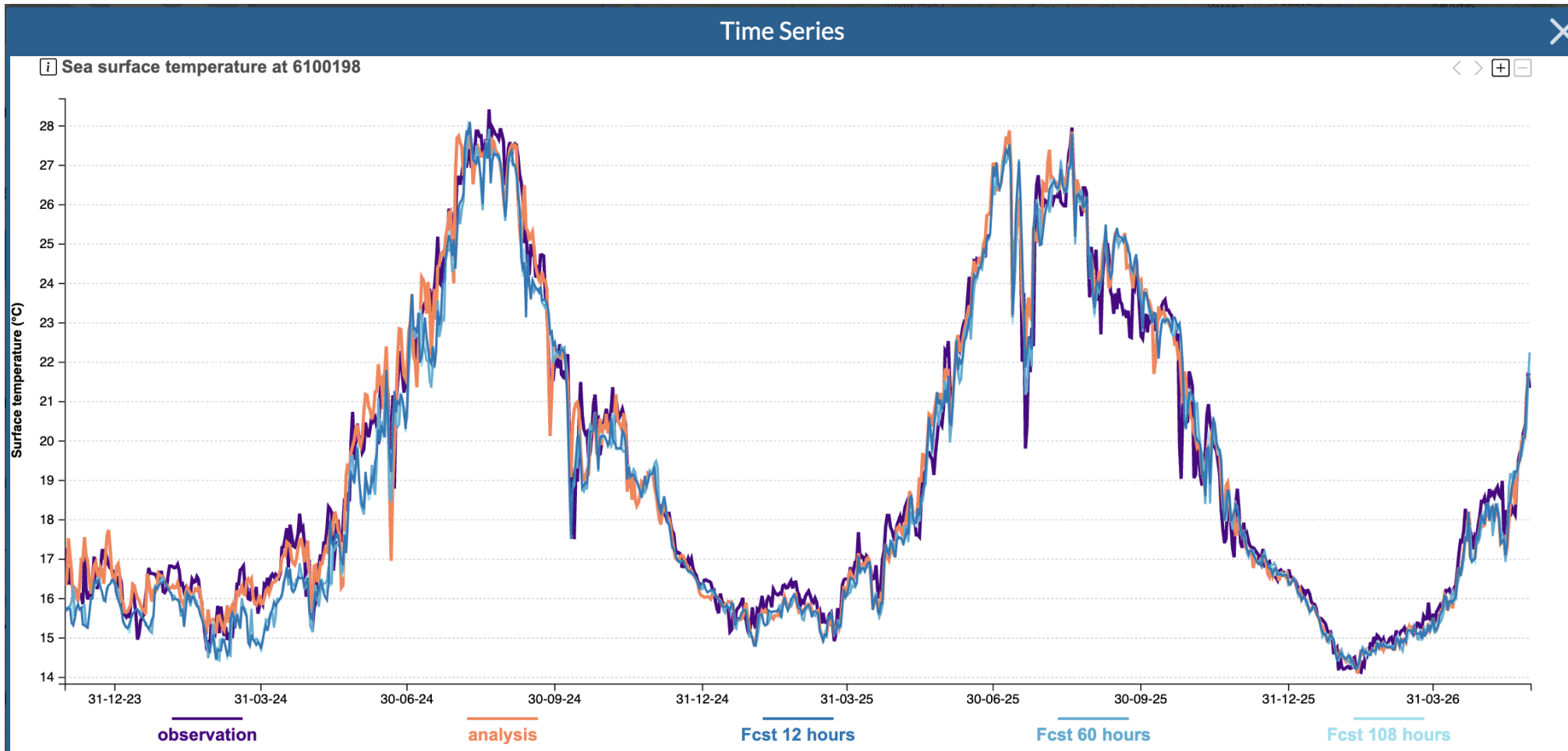
CMEMS PQ Dashboard – CLASS2



Temperature

Model @ surface
VS
In-situ moorings

CMEMS PQ Dashboard – CLASS2



Temperature

Model @ surface
VS
In-situ moorings

Mediterranean Sea Forecasting System Operational Validation

1. CMEMS PQD: <https://marine.copernicus.eu/user-corner/>
2. CMCC Website: <https://medfs.cmcc.it/>

CLASS4 & CLASS2 & CMEMS PQD: monitoring over the Med Sea along 5 vertical depths Weekly update

CLASS4 - misfits
SLA 3D Temperature 3D Salinity

CLASS2
Surface: temperature, salinity, sea level

Depth [m]	
1	8
2	30
3	150
4	300
5	600

CLASS2 Temp. Freq.	Analysis	Forecast 01	Forecast 03	Forecast 05
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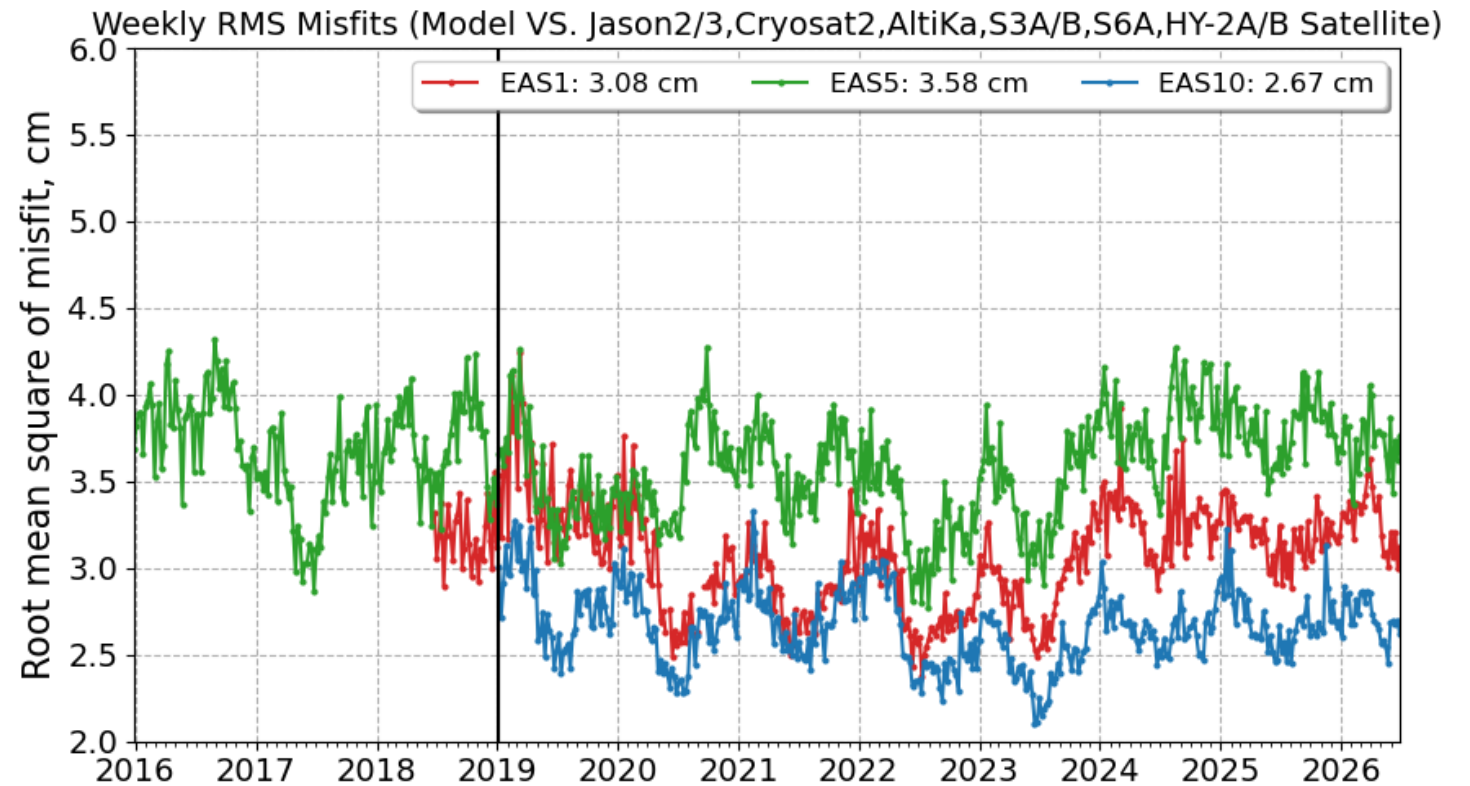
PQ Metrics	Mean	Bias	RMSD
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System	Resolution	NEMO	Tides
EAS1	1/16° – 72 v. lev	v3.2	NO
EAS5	1/24° – 141 v. lev	v3.6	NO
EAS10*	1/24° – 141 v. lev	v4.2	YES

* Latest operational CMEMS system

CMCC Website – CLASS4 SSH, T, S RMSE Timeseries

EAS1 EAS5 EAS10: Sea Level Anomaly [cm]



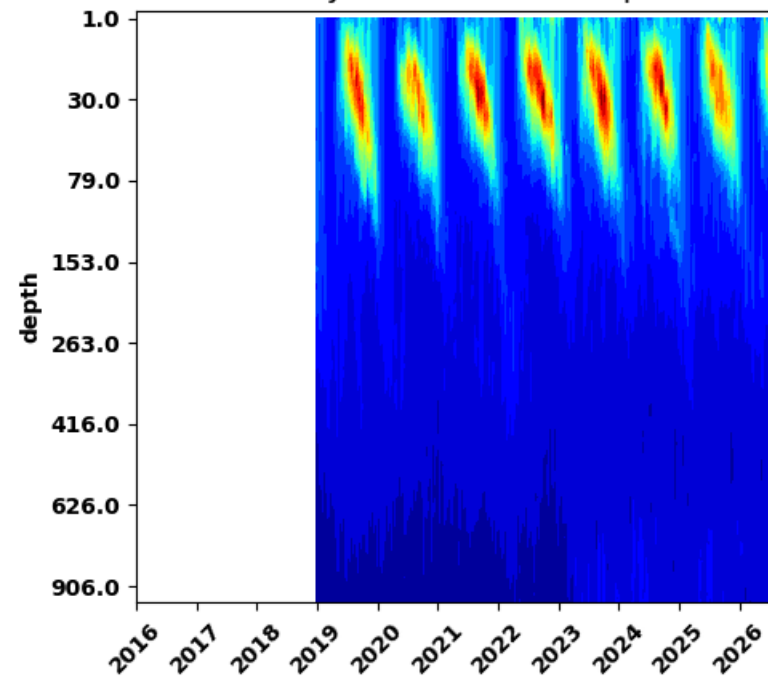
Sea Level Anomaly

Model @ surface
VS
Satellite SLA L3

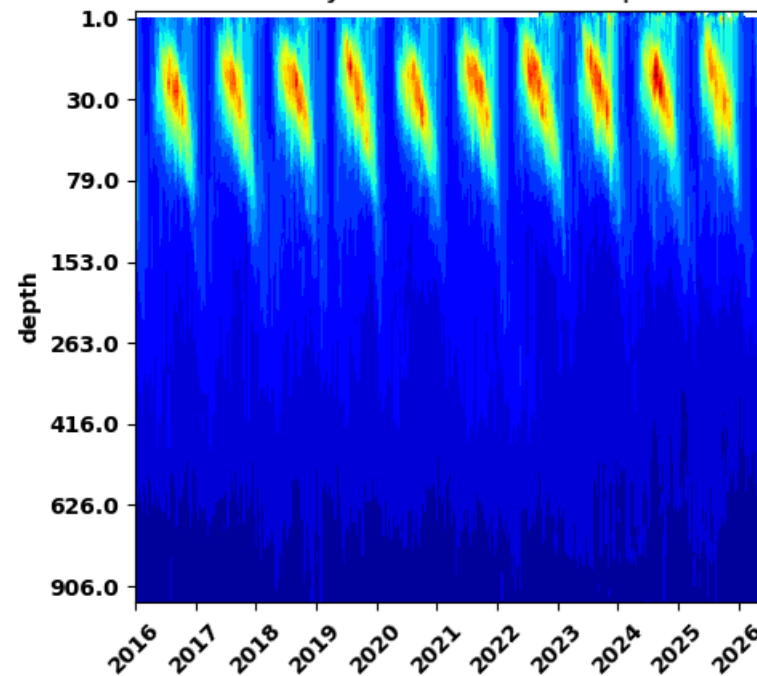
CMCC Website – CLASS4 T & S Hovmoller Depth-time

System	Resolution	NEMO	Tides
EAS1	1/16° – 72 v. lev	v3.2	NO
EAS5	1/24° – 141 v. lev	v3.6	NO
EAS10	1/24° – 141 v. lev	v4.2	YES

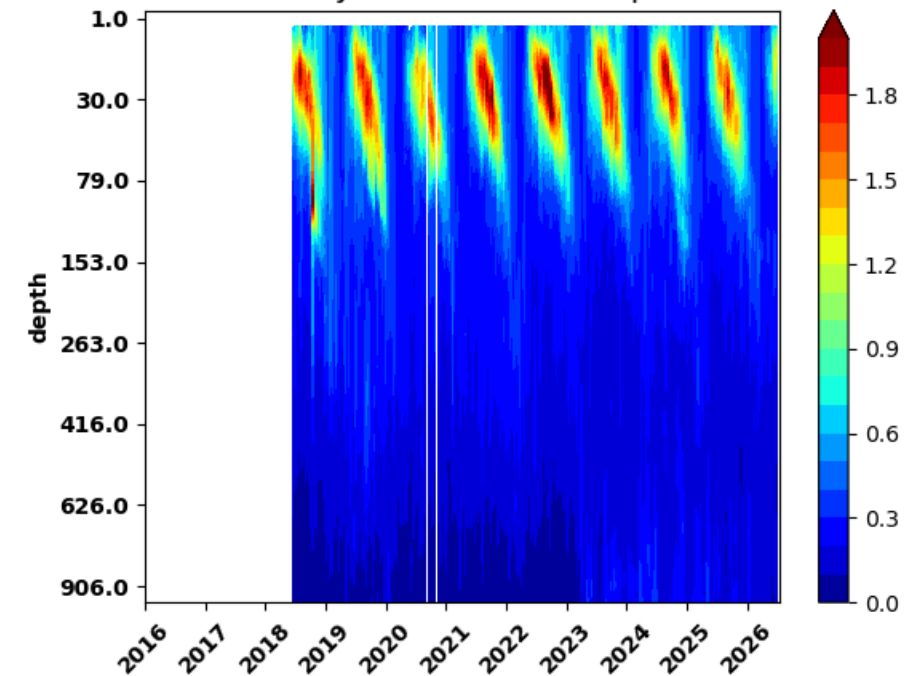
EAS10 Temperature [° C]
Weekly RMS Misfits at depth



EAS5 Temperature [° C]
Weekly RMS Misfits at depth



EAS1 Temperature [° C]
Weekly RMS Misfits at depth



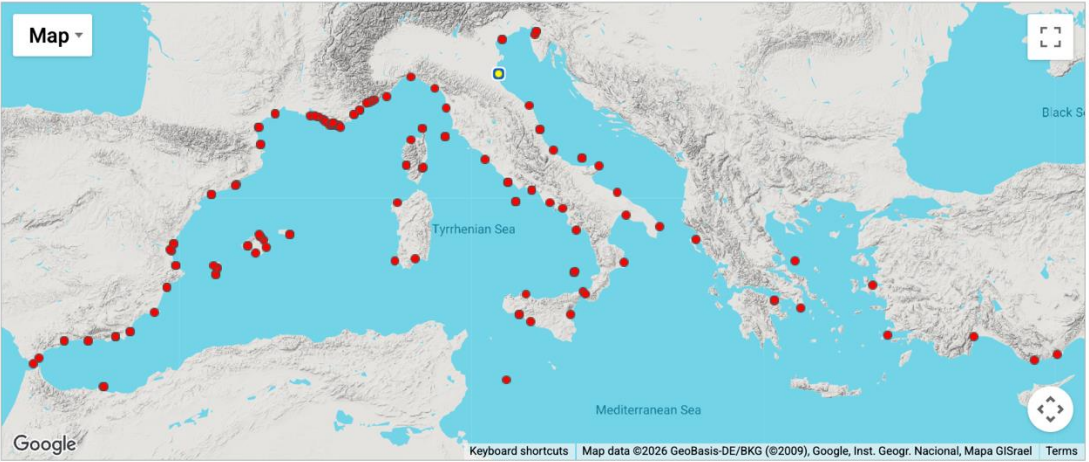
CMCC Website – CLASS2

Sea Level
Temperature
Salinity

EMODnet
REAN24
EAS1
EAS5
EAS9
EAS10

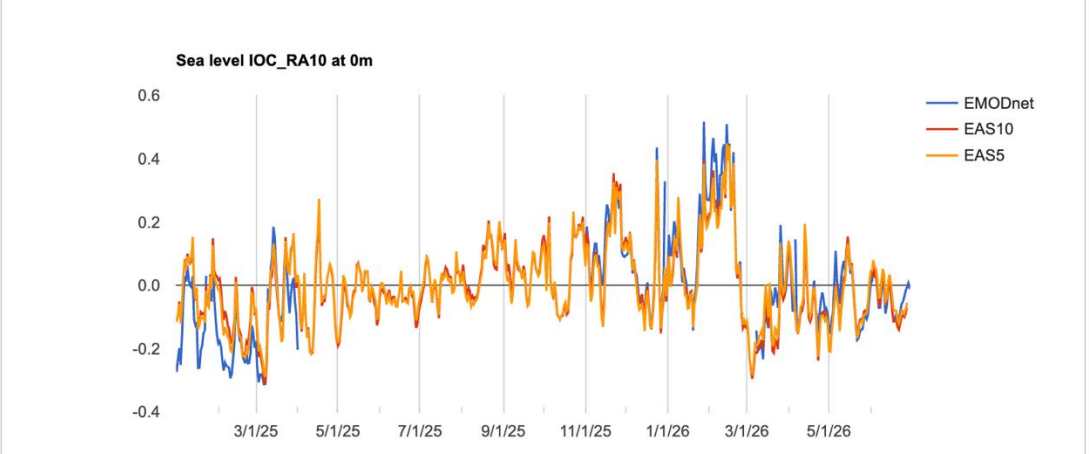
Tide Gauges and Mooring Validation

Map



Keyboard shortcuts | Map data ©2026 GeoBasis-DE/BKG (©2009), Google, Inst. Geogr. Nacional, Mapa GISrael | Terms

Sea level IOC_RA10 at 0m



EMODnet

EAS10

EAS5

Datasets

code	begin	end
EMODnet	2015-01-01	2026-07-10
EAS1	2018-07-01	2026-06-29
EAS5	2015-01-01	2026-06-28
REAN24	2015-01-01	2026-05-31
EAS9	2023-01-01	2025-12-21
EAS10	2023-01-01	2026-06-28

Sea level

buoy: IOC_RA10

depth: 0 m

EAS10

bias = 0.001

RMS = 0.072

EAS5

bias = 0.001

RMS = 0.069

Data Filter

Parameter: Sea level

Source #0: EMODnet

Source #1: EAS10

Source #2: EAS5

Begin: 2025-01-01

End: 2026-06-30

Apply filter

Platforms

IOC_RA10

IOC_RC09

IOC_rous

IOC_SA16

IOC_sagu

IOC_SB36

IOC_SC43

IOC_sete

IOC_sole

IOC_TA18

IOC_tarr

IOC_tasu

IOC_toul

IOC_TR22

IOC_yale

Depth

0

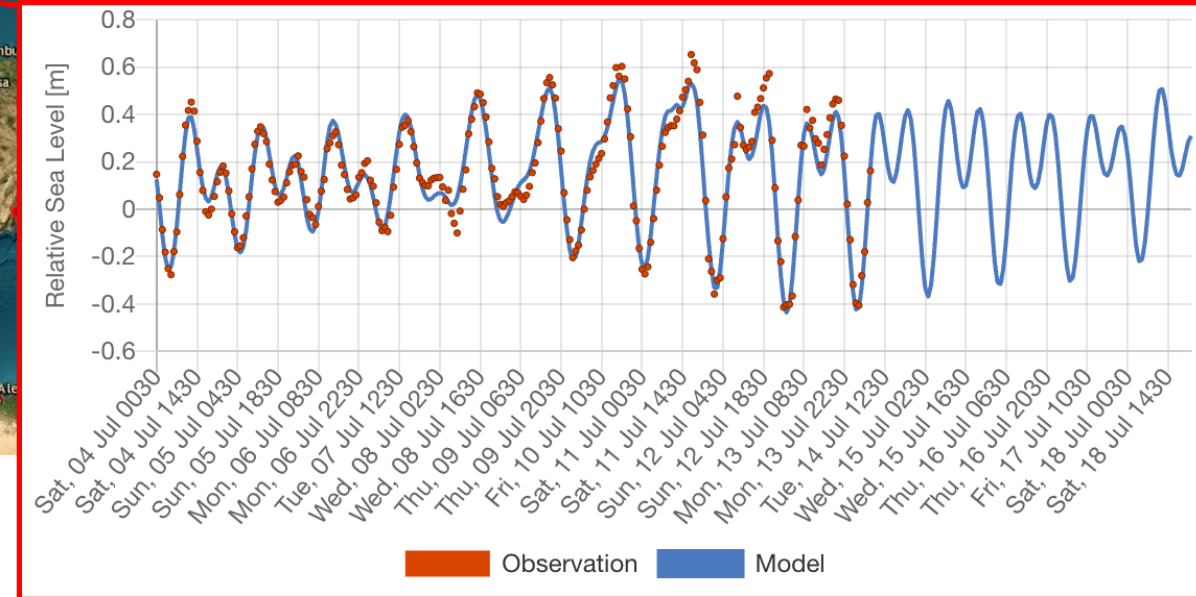
Difference mode

Save plot as PDF...

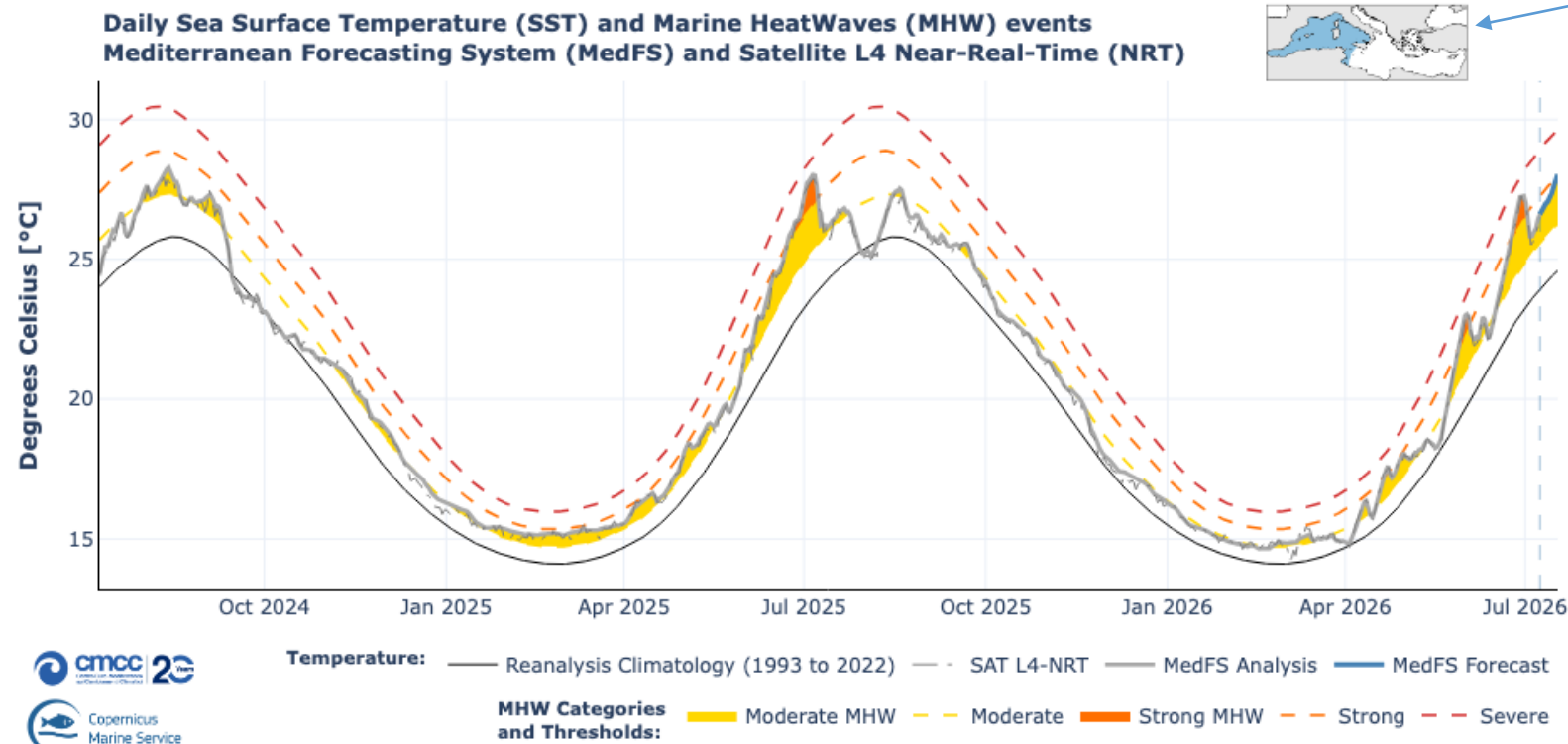
Save data as CSV...

All platforms statistics...

CMCC Website – MedFS Monitoring



CMCC Website – MedFS Monitoring



Eastern Med Sea
Western Med Sea
Adriatic Sea
North Adriatic Sea
South Adriatic Sea
Aegean Sea
Ligurian Sea
Gulf of Taranto

Thanks

Questions?



cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici

www.cmcc.it

