

The new Mediterranean Sea analysis and forecasting system including tides: description and validation



Emanuela Clementi (1), Anna Chiara Goglio (1), Ali Aydogdu (1), Jenny Pistoia (1), Romain Escudier (1), Massimiliano Drudi (2), Alessandro Grandi (2), Antonio Mariani (2), Vladislav Lyubartsev (2), Rita Lecci (2), Sergio Cretí (2), Simona Masina (1), Giovanni Coppini(2), Nadia Pinardi (1,3)

(1) Ocean Modeling and Data Assimilation Division, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy

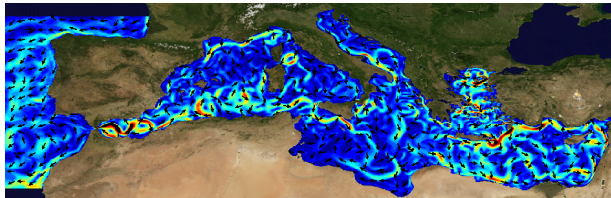
(2) Ocean Predictions and Applications Division, Centro Euro-Mediterraneo sui Cambiamenti Climatici, Italy

(3) Department of Physics and Astronomy, University of Bologna, Italy

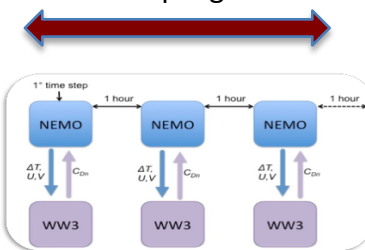
CMEMS Med-PHY NRT System and Product

Ocean General Circulation Model (OGCM) based on **NEMO v3.6**

Hor. Res. = $1/24^\circ$ (~ 4.5 km)
Vert. Res. = 141 z* vertical

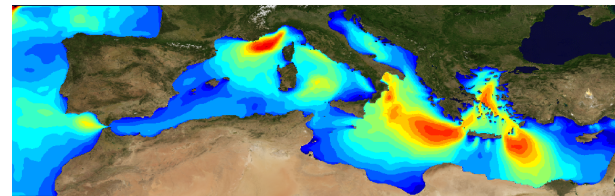


2-way hourly
coupling



Wave model **WaveWatch-III v3.14**

Hor. Res. = $1/24^\circ$ (~ 4.5 km)
Spectral discretization:
30 freq. & 24 directional bins



The product

MEDSEA_ANALYSIS_FORECAST_PHY_006_013
Hourly + Daily + Monthly mean:

- 2D Sea Surface Height
- 3D Salinity
- 3D Potential Temperature
- 3D Zonal/Meridional currents
- 2D MLD
- 2D Bottom Temperature

Ocean variational data assimilation scheme: **OceanVar**

Satellites SLA and T/S insitu observations
are jointly assimilated
Non-solar heat flux correction is achieved
through satellite SST



CMEMS Med-PHY NRT forcing fields

ECMWF 1/10° atmospheric fields

MSLP, CC, 2m RelH, 2m T, 10m Wind speed, Precip

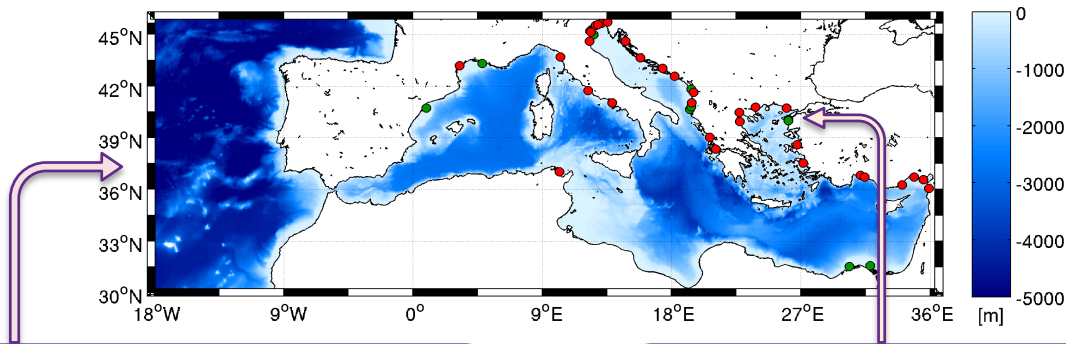
Temporal resolution:

Forecasts: 1hr, 3hrs, 6hrs

Analysis: 6 hours time resolution

Land river inputs:

Surface boundary condition for **39** major rivers with annual mean discharge $> 50 \text{ m}^3/\text{s}$ using climatological monthly mean values



Lateral Boundary conditions in the Atlantic:

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

Lateral Boundary conditions in the Dardanelles Strait:

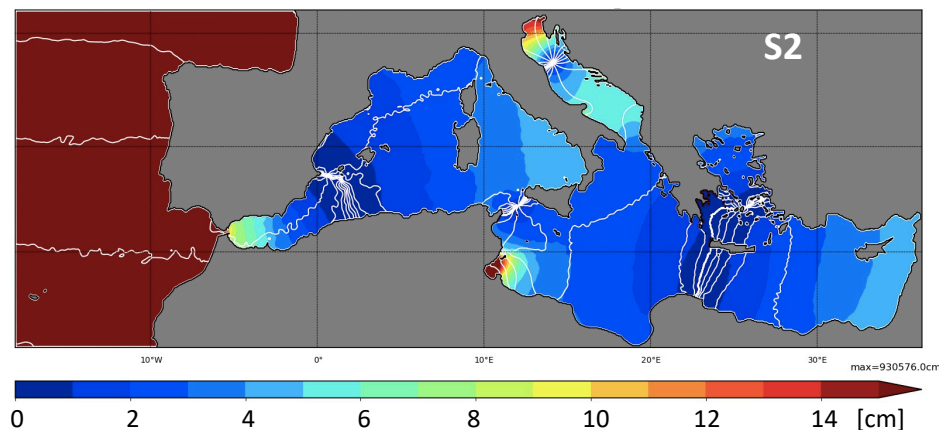
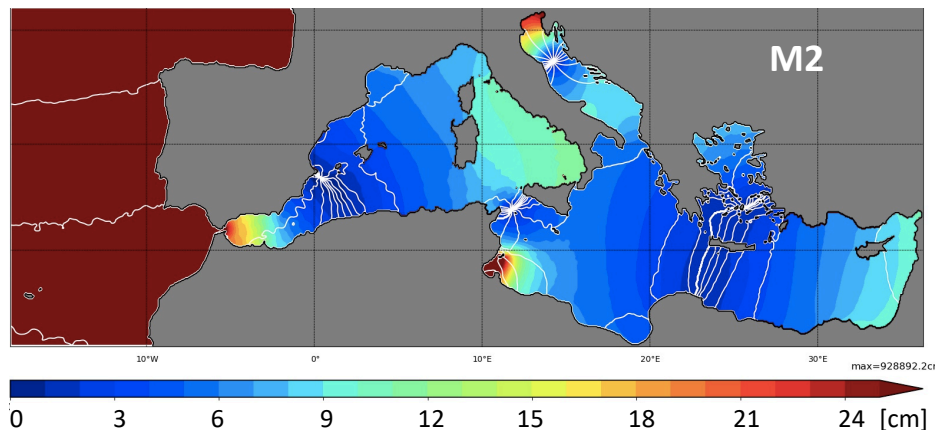
Turkish Straits System (TSS) box model (Maderich et al. 2015) daily climatologies & Temperature from CMEMS GLO-MFC

CMEMS Med-PHY NRT: tides

Tides and their interactions with the complex dynamics of the Mediterranean Sea represent a crucial and important challenge

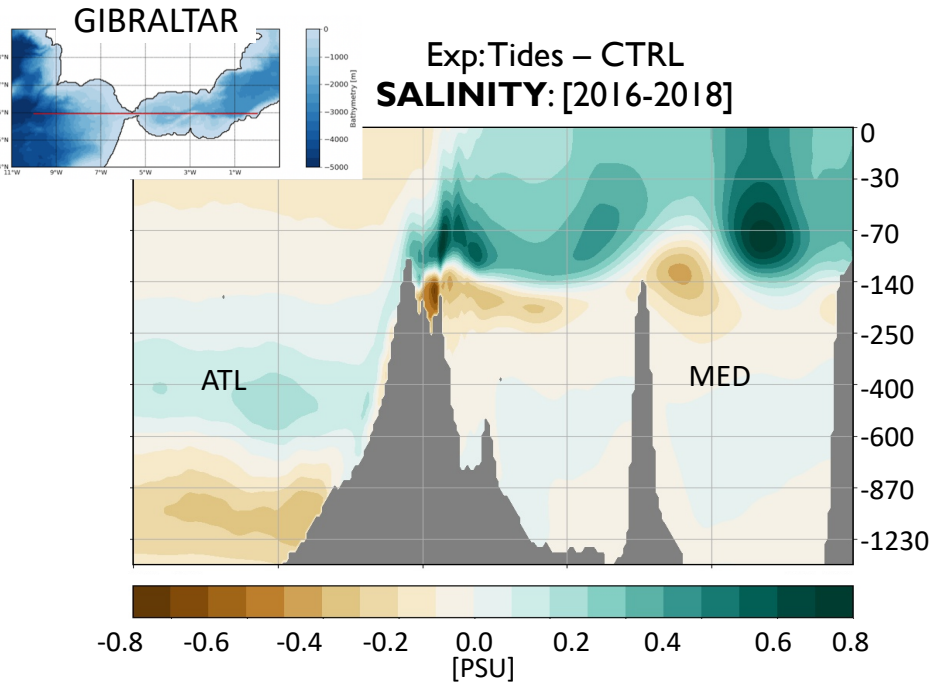
From the May 2021 CMEMS delivery → new system including tides

- ✓ 8 tidal components are included: M2, S2, N2, K2, K1, O1, Q1, P1
- ✓ Tidal BDY in the Atlantic from FES2014 (SSH) + TUGO (UV)
- ✓ Assimilation of tidal signal from SLA satellite data



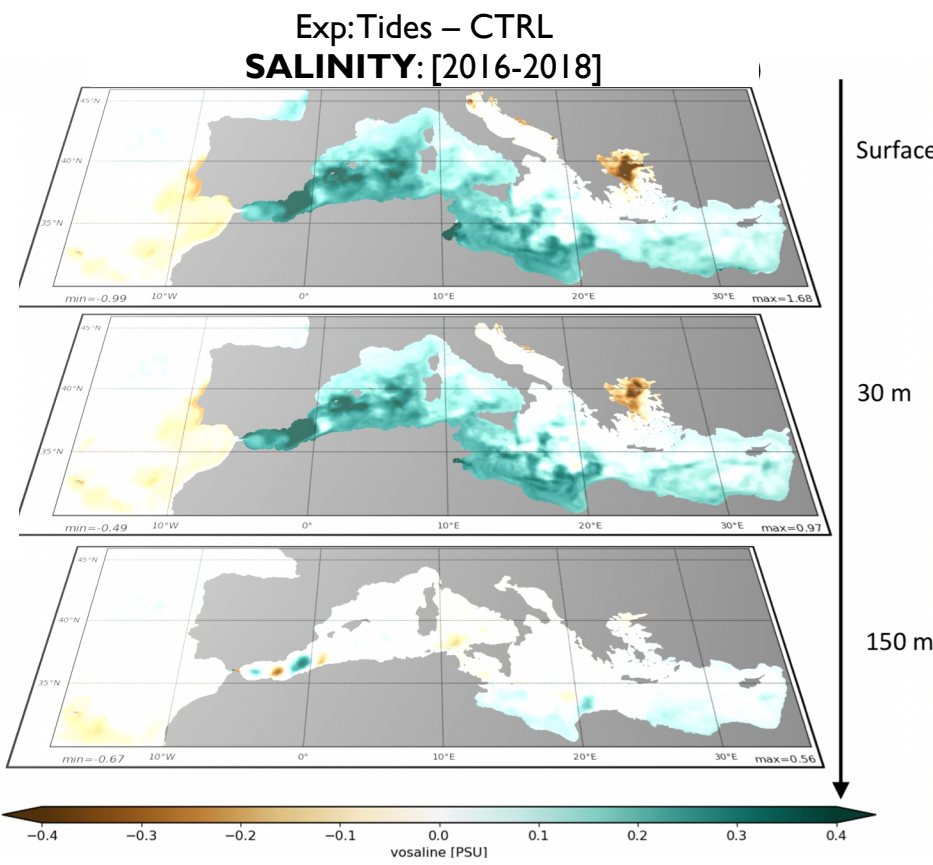
In addition to standard variables, detided sea level will be provided to the users

CMEMS Med-PHY NRT: tides



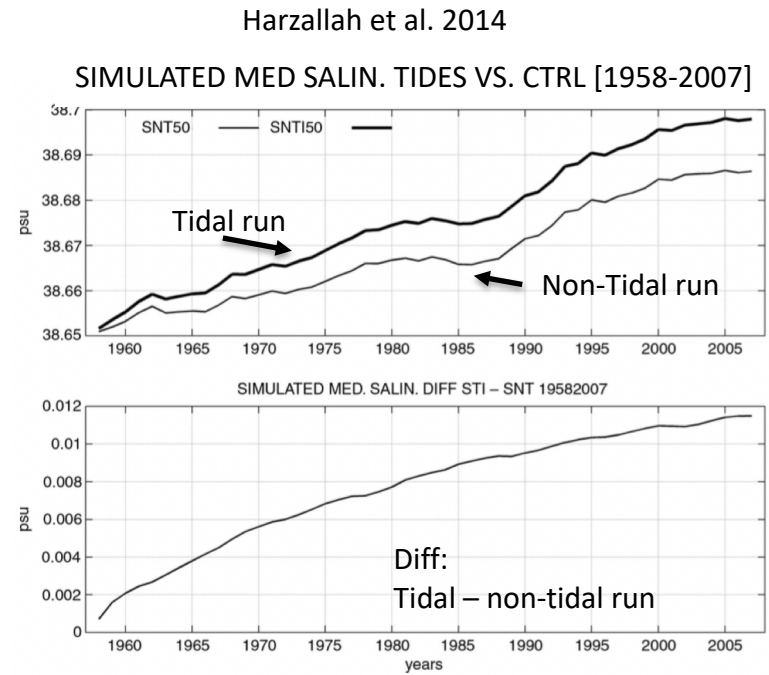
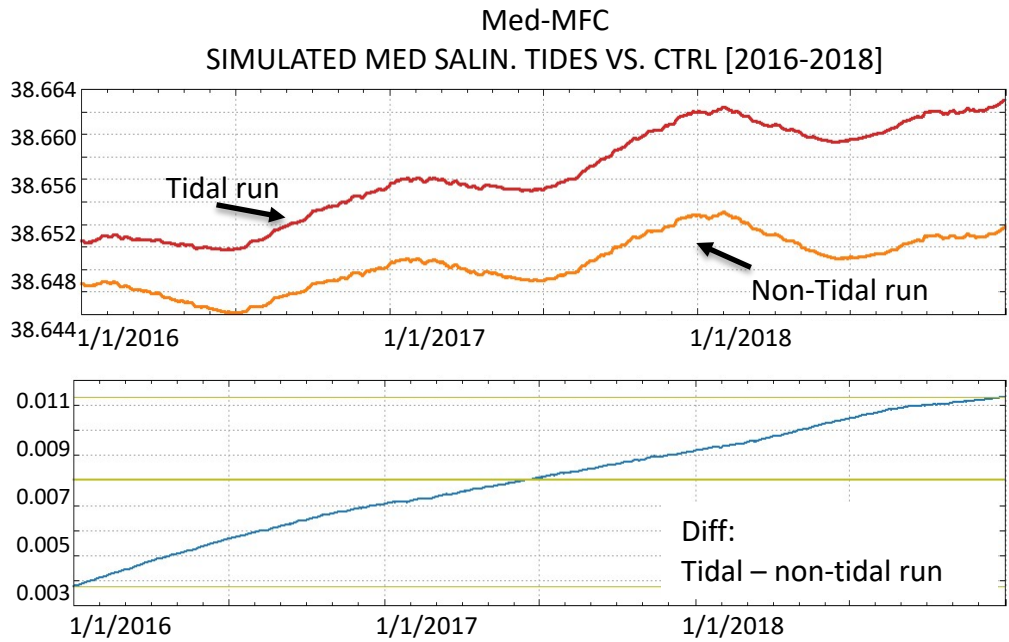
When tides are included, salinity increases in the Mediterranean Sea, especially in the surface layers.

This increase mainly due to a change of the Gibraltar salt flux.



CMEMS Med-PHY NRT: tides

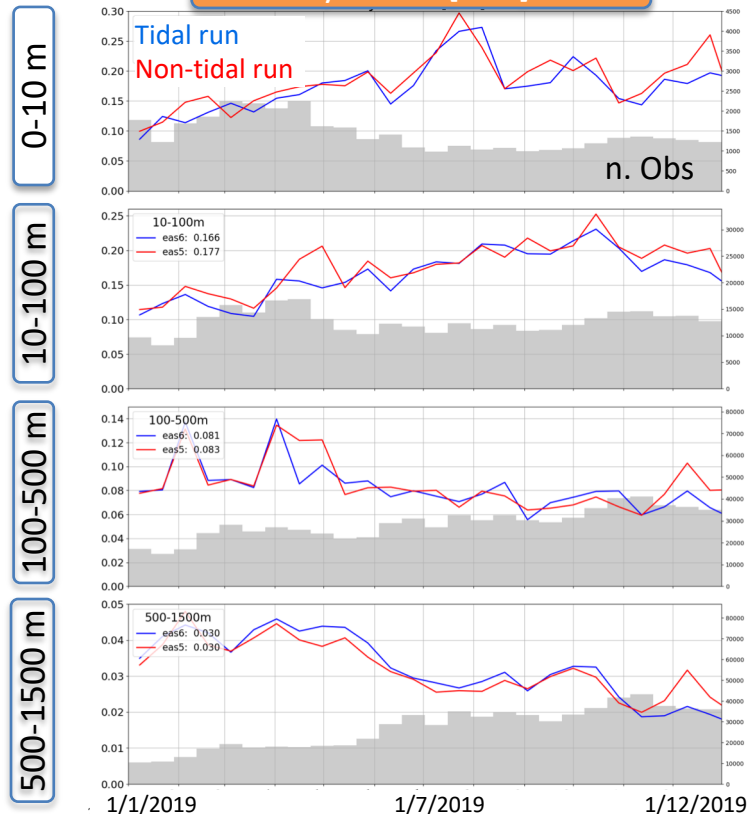
Basin average salinity: Med-MFC VS. Literature



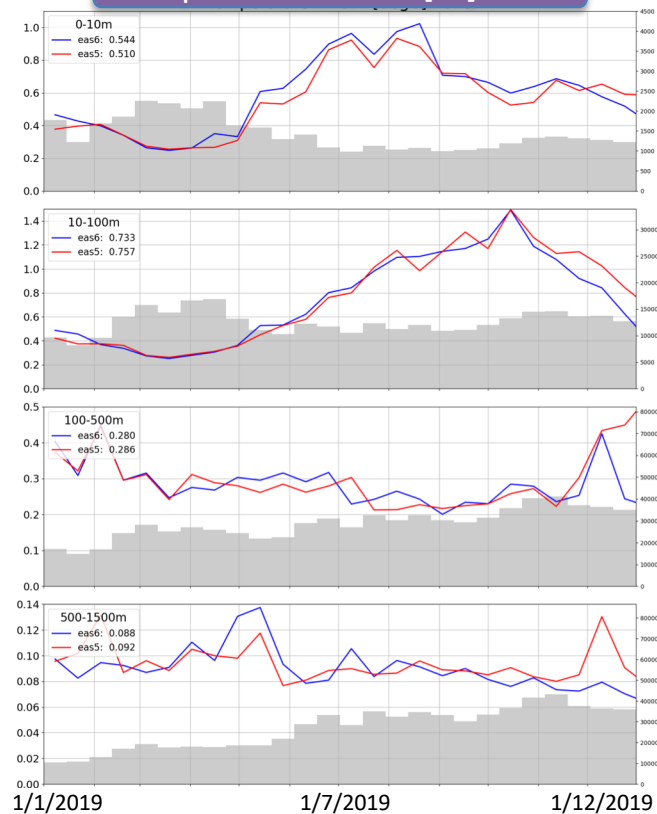
*The Med Sea mean salinity increases when including tides.
Results are in agreement with previous literature outcomes (Harzallah et al., 2014)*

CMEMS Med-PHY NRT: T/S validation

Salinity RMSD [PSU] 2019



Temperature RMSD [°C] 2019



Salinity

Larger error @ surface layers.

Tidal run:

Slightly decrease of the error @ all layers

Temperature

Larger error in the thermocline during summer season.

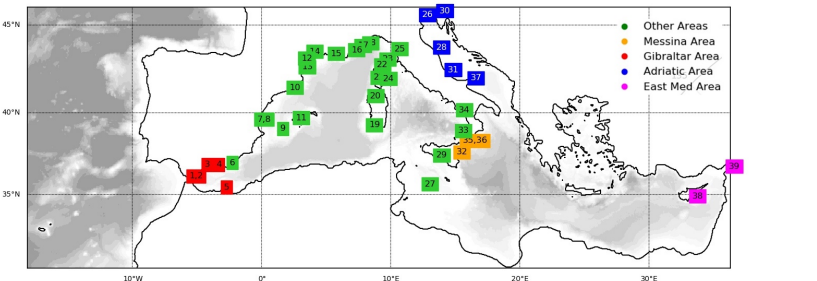
Tidal run:

Slightly increase of the error @ [0-10m] and decrease of the error @ deeper layers

CMEMS Med-PHY NRT: Harmonic Analysis

Model Tidal Amplitude and Phase compared to Tide Gauges

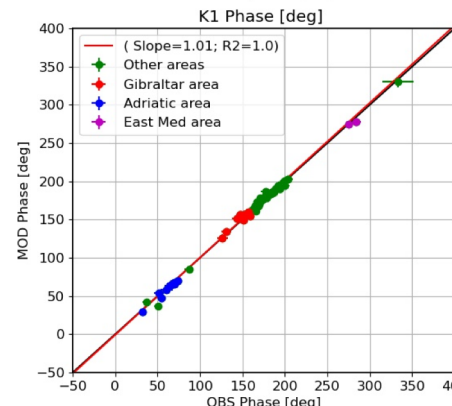
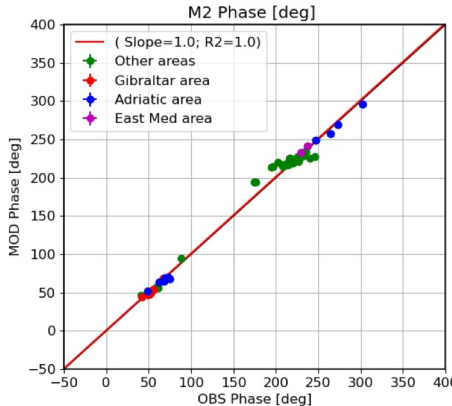
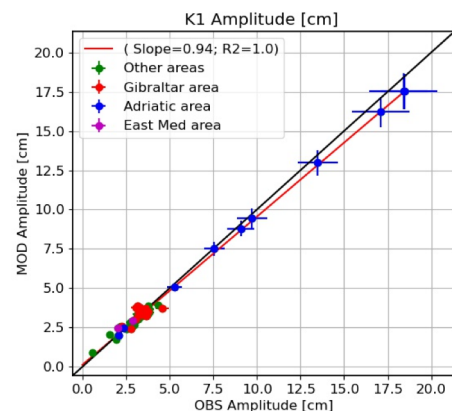
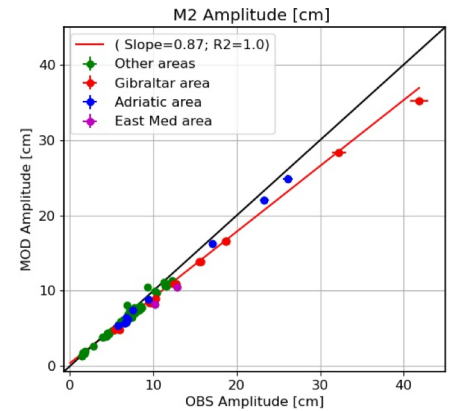
- 39 tide gauges
- 6 months harmonic analysis



$$RMSd = \sqrt{\frac{1}{2N} \sum_{n=1}^N [(A_{mod} \cos \phi_{mod} - A_{ref} \cos \phi_{ref})^2 + (A_{mod} \sin \phi_{mod} - A_{ref} \sin \phi_{ref})^2]}$$

Comp	M2	S2	K1	O1	N2	P1	Q1	K2
RMSD [cm]	1.5	0.7	0.3	0.3	0.3	0.2	0.2	0.3

Tidal amplitudes and phases are correctly represented by the model when compared to tide gauges



CMEMS Med-PHY NRT: Harmonic Analysis

Comparison with Literature

Vectorial distance between model and a sub-set of tide gauges (#15) used in previous literature evaluations

Mean Vectorial distances [cm]	M2	S2	K1	O1
CMEMS MedFS	1.78	0.99	0.44	0.40
Tsimplis et al., 1995	1.75	1.21	1.48	0.46
Palma et al., 2020	1.74	0.93	1.50	0.77

CMEMS MedFS system has in general a better skill wrt previous literature analysis

Comparison with TPXO: Barotropic Global Tidal Model

Tidal Component	Mean Vectorial distances [cm]
M2	1.91 cm
S2	1.14 cm
K1	0.42 cm
O1	0.21 cm
N2	0.31 cm
P1	0.21 cm
Q1	0.12 cm
K2	0.44 cm

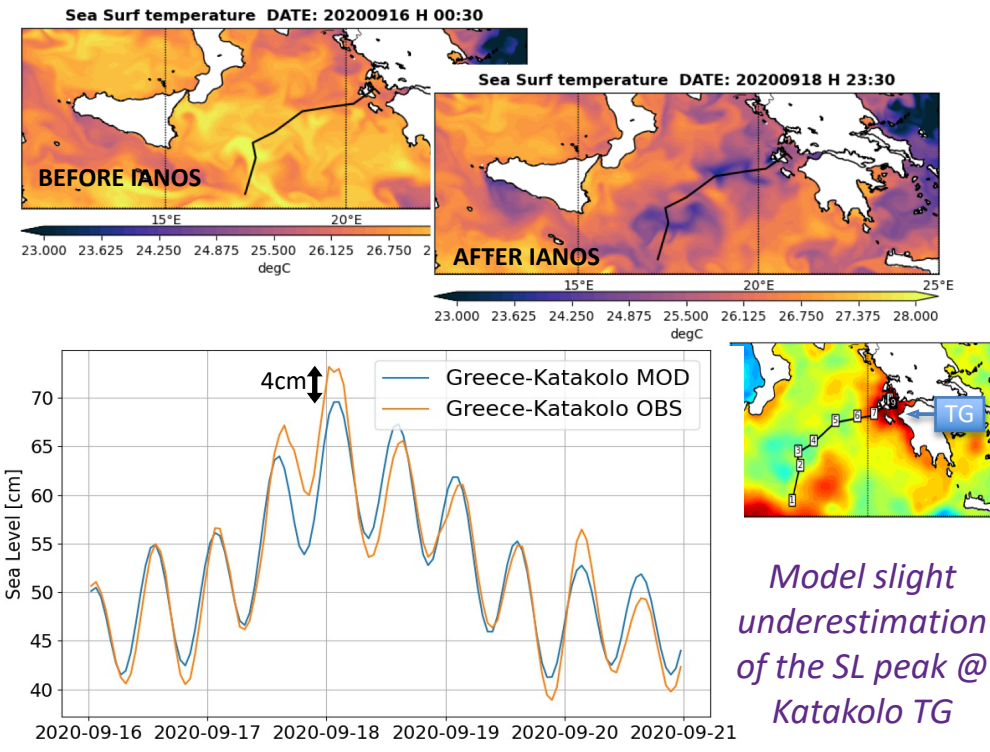
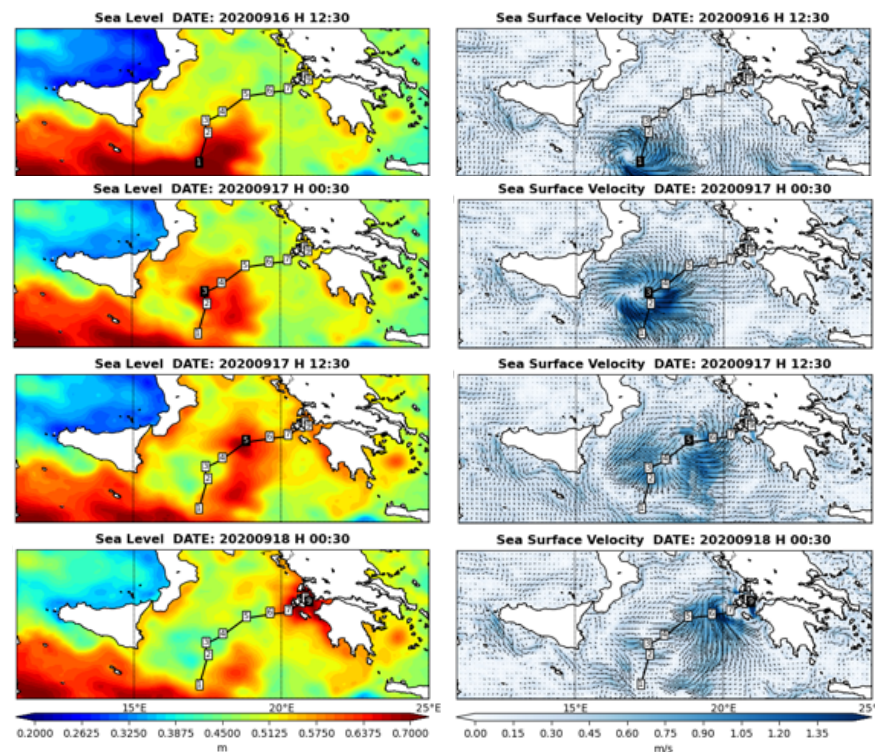
CMEMS MedFS system has larger errors for M2 and S2 components which are the ones providing the larger tidal elevation in the Mediterranean Sea

CMEMS Med-PHY NRT: Analysis of Ianos Medicane

Medicane Ianos: rare Mediterranean tropical-like cyclone impacting Greece on 17-20 Sept. 2020

Sea Level and Surface Currents increase along the Min. Atm. Pressure path starting from 16/09/2021 (every 6 hours)

Sea Surface Temperature decreases of ~4°C in the Ionian Sea after Ianos passage



Model slight underestimation of the SL peak @ Katakolo TG

Conclusions

- From May 2021 an upgraded CMEMS Mediterranean Physical product including tidal waves will be delivered
- The tidal potential is calculated for the Mediterranean Sea 8 major tidal constituents: M2, S2, N2, K2, K1, O1, P1, Q1
- The system is forced by tides in the Atlantic open boundary
- The system has a slightly improved skill wrt the non-tidal system when comparing temp/sal with *insitu* observations
- The tidal amplitudes and phases are correctly represented by the model: high skill when compared to *insitu* tide gauges, previous works and TPXO barotropic solution
- The tidal system has correctly represented the evolution of medicane Ianos and its increased sea level at available observations



Thanks

