OceanPredict '19

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Advancing the science and application of ocean predictions

The Mediterranean analysis and forecasting physical system for the Copernicus Marine Service: description and skill assessment

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OUTLINE

- Mediterranean Forecasting System overview in the CMEMS framework
- System description
  - Main differences between actual and previous modeling system
  - Major impacts of the implemented modifications on the new system
- System validation with in-situ, satellites and climatological datasets
- Overview of future upgrades
- Summary & Conclusions

Med-Physics Products in CMEMS

CMEMS Med-MFC is one of the 7 CMEMS MFCs

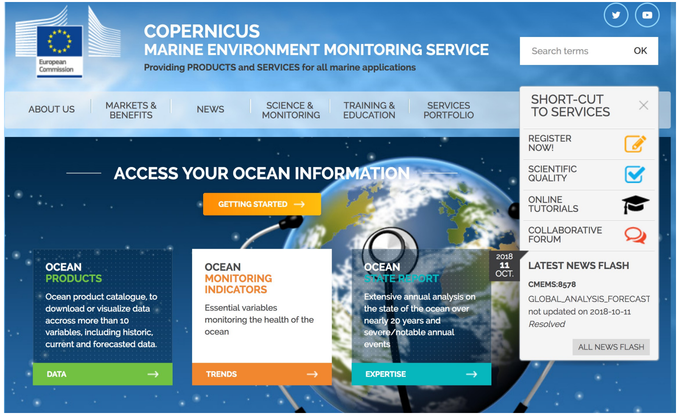
A consortium of 3 research institutes:

CMCC (Leader of the consortium and responsible for the Physical product)

OGS (Responsible for the Biogeochemical product)

HCMR (Responsible for the Wave product)

http://marine.copernicus.eu/



2 CMEMS Med-PHY Products

MEDSEA_ANALYSIS_FORECAST_PHY_006_013

Hourly + Daily + Monthly mean: 2016-ogoing

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

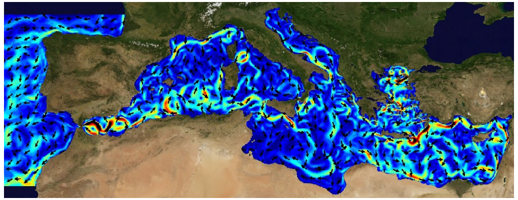
MEDSEA_REANALYSIS_PHY_006_004

Daily + Monthly mean: 1987-2017

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

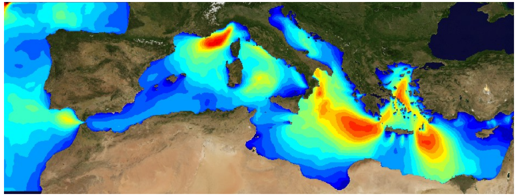
Med-Physics Analysis and Forecast system

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

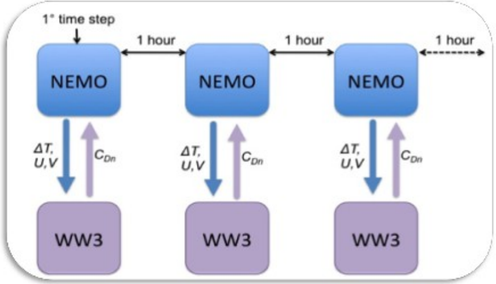


2-way hourly coupling

Wave model WaweWatch-III (WW3) v3.14



Hor. Res. = 1/24o (~4.5 km)
Vert. Res. = 141 z* vertical levels with partial cells



Hor. Res. = 1/24o (~4.5 km)
Spectral discretization:
* 30 freq. bins (0.05-0.79 Hz)
* 24 directional bins

<u>The two-way coupling consists of inputting</u>:
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

Med-Currents Analysis and Forecast system: Forcings

ECMWF 1/8o atmospheric fields:

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

Temporal resolution:

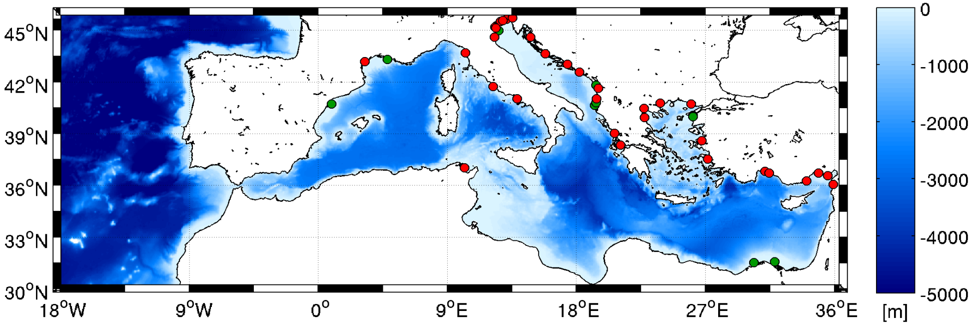
Forecasts: 3hrs for the first 3 days and 6 hours for the next 7 days

Analysis: 6 hours time resolution

Land river runoff:

vertical boundary condition for **39** major rivers (**previous version 7**) with annual mean discharge > 50 m3/s using climatological monthly mean seasonal cycle values

The Dardanelles inflow is parameterized through a river-like parametrization



Lateral Boundary conditions in the Atlantic:

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

- Flather boundary condition (Flather, 1976) is applied to barotropic velocities
- Orlansky npo boundary condition (Orlanski, 1976) is applied to tracers and baroclinic velocities

Med-Currents Analysis and Forecast system: Data Assimilation

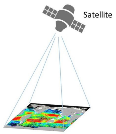
Model solutions are corrected by the data assimilation

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

The assimilated data are:

Along track Sea Level Anomaly from CMEMS SL-TAC

- Jason 2/2N, 3
- Cryosat2
- Saral/AltiKa
- Sentinel3A

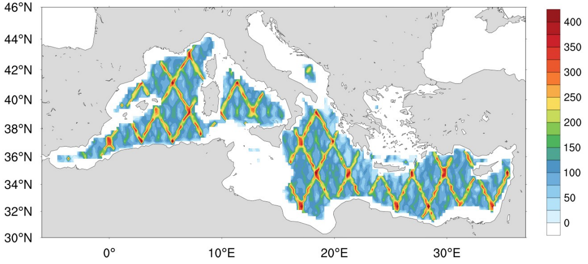


Vertical profiles of Temperature and Salinity from CMEMS InSitu TAC:

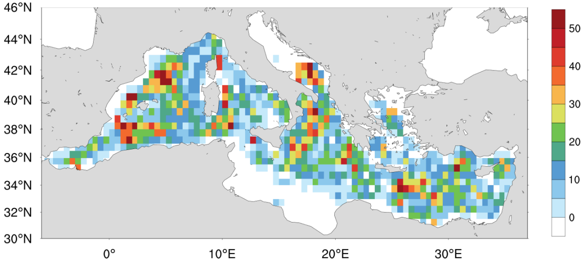
Argo

XBT

SLA data assimilated in 2016-2017



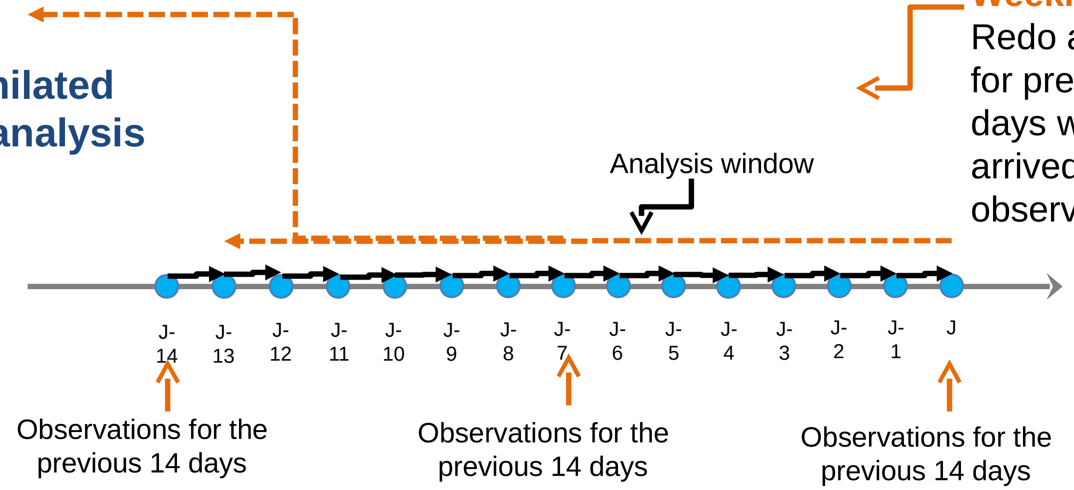
ARGO data assimilated in 2016-2017



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

Med-Currents Analysis and Forecast system: Data Assimilation

The data are assimilated weekly with a daily analysis window



Weekly cycle: Redo analyses for previous 14 days with newly arrived observations

Bi-Weekly assimilation cycle because data of higher quality is available

Production chain

ANALYSIS: Each Tuesday → simulation for the previous 2 weeks with ECMWF analysis atmo. forcing + assimilation correction

HINDCAST: Every day the initial condition for the forecast cycle is generated by a model simulation for the previous 24hr hours and forced by ECMWF analysis fields

FORECAST: Computed for next 10 days forcing the numerical model with ECMWF forecast fields

Med-Currents Analysis and Forecast system description

Main differences between actual and previous modeling system

Previous system EAS1	Feature	Actual system EAS3
1/16° (5-6km) hor 72 vert lev	**Resolution**	1/24° (4-5km) hor 141 vert lev
NEMO v3.4 linear free-surface Z coord.	**OGCM model**	NEMO V3.6 non-linear free-surface Z* coord
7	**N. of river inputs**	39
1.2e-5 / 1.2e-6 [m2/s]	**vertical background viscosity / diffusivity values**	1.2e-6 / 1.0e-7 [m2/s]
-6.e8 / -1.e9 [m4/s]	**horizontal bilaplacian eddy diffusivity / viscosity**	-1.2e8 / -2.e8 [m4/s]
300sec	**Time step**	240sec
SDN Clim T/S	**Initial Conditions**	WOA-V2 Winter Clim T/S
From modified DBDB1 1min	**Bathymetry**	From modified GEBCO 30arc-sec
Dobricic and Pinardi (2008)	**Data Assimilation**	Storto et al. (2015) adapted for the Mediterranean Sea

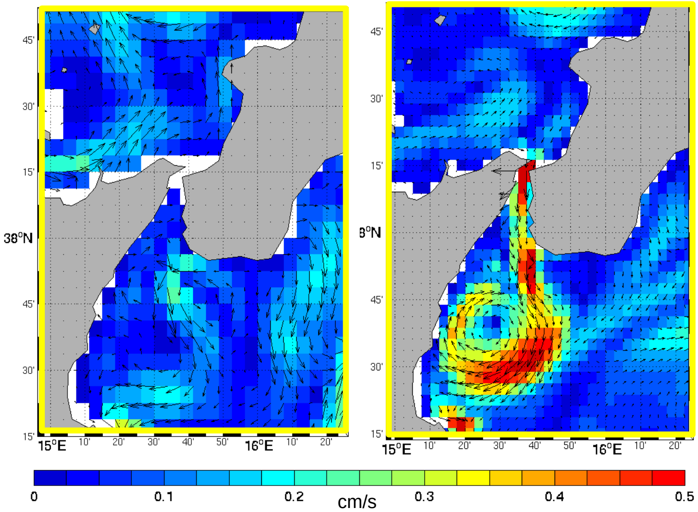
Common parameterizations

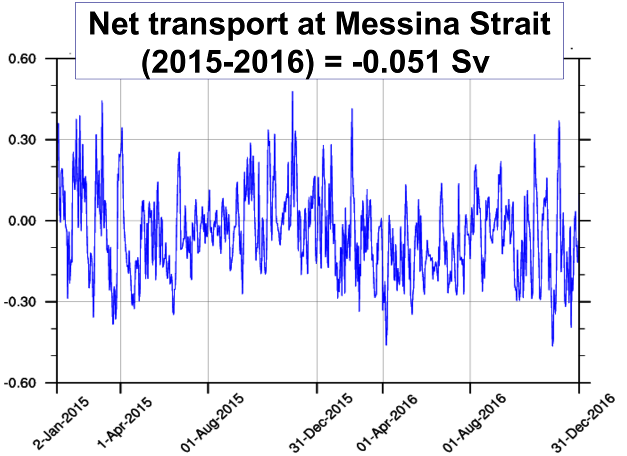
- Air-sea fluxes: MFS bulk formulae described in Pettenuzzo et al. (2010)
- Advection scheme for active tracers: mixed up-stream/MUSCL
- Vertical diffusion and viscosity terms: Function of the Richardson number as parameterized by Pacanowsky and Philander (1981)

Impacts due to increased resolution

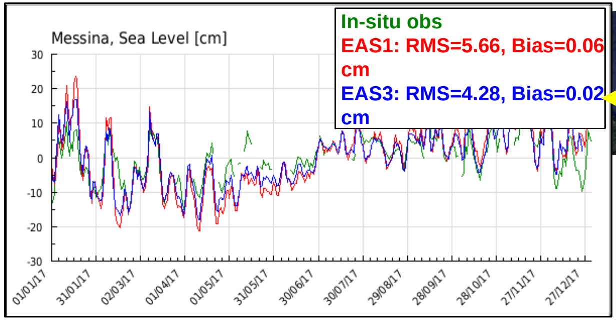
MESSINA STRAIT

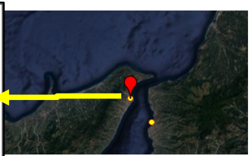
EAS1 (1/16o) **EAS3 (1/24o)**

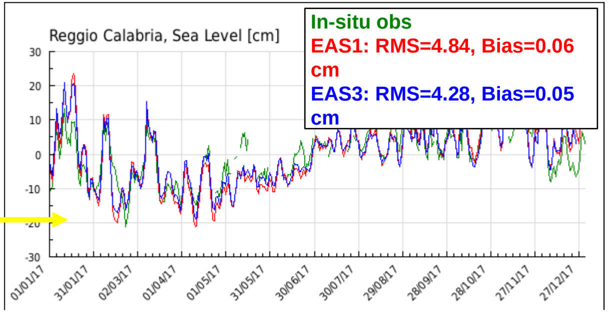




Sea Level comparison

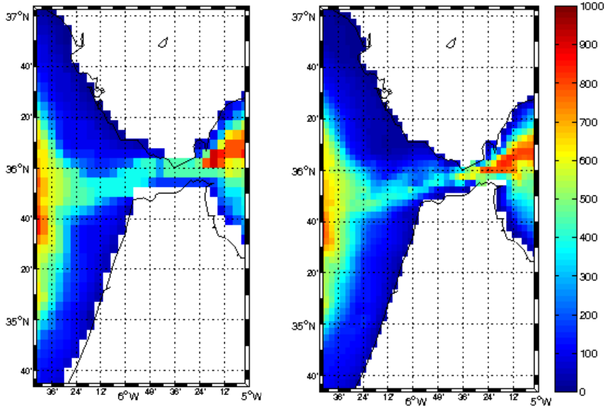


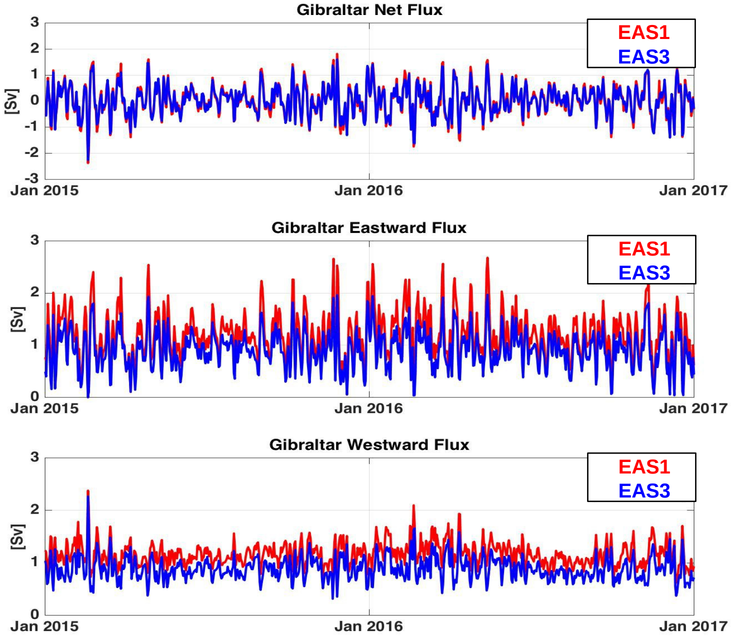


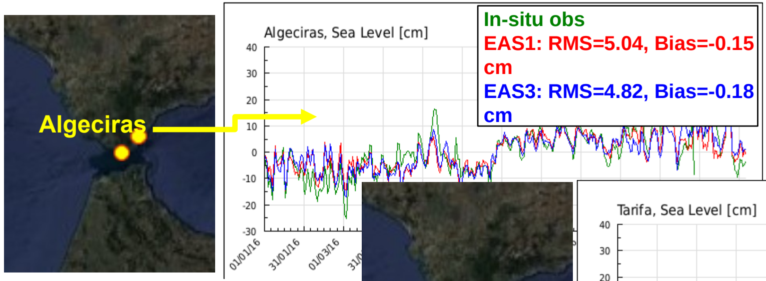


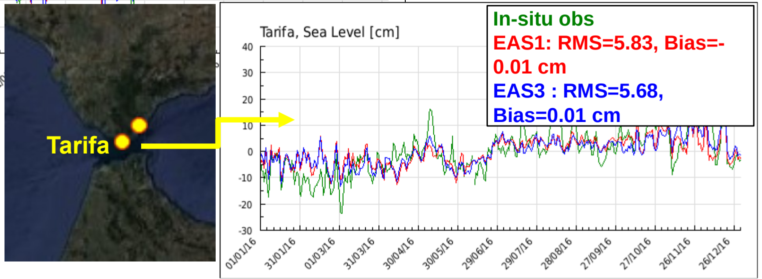
Impacts due to increased resolution

EAS1 (1/16o) **EAS3 (1/24o)**









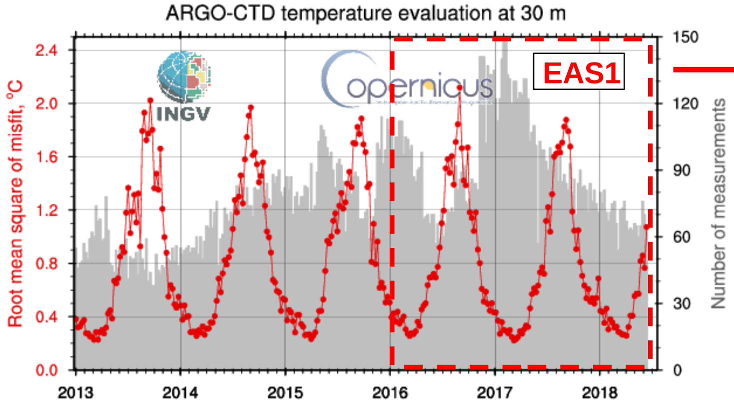
Sea Level comparison

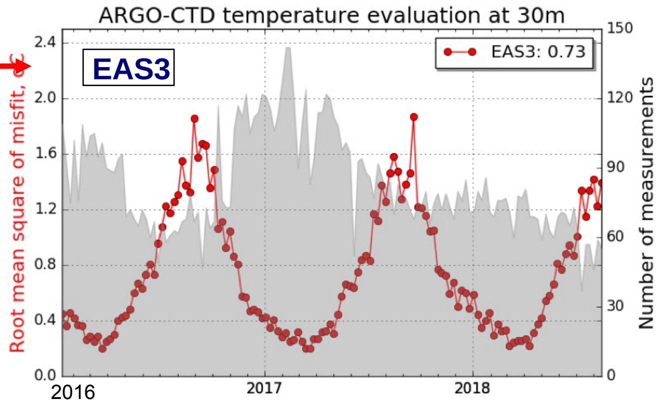
Gibraltar Mean Flux *[Sv]*	**EAS 1**	**EAS 3**	Soto-Navarro et al., 2010
Net	0.032	0.04	0.038 ± 0.007
Eastward	1.20	0.907	0.81 ± 0.06

Quasi-Independent Validation: MISFITS

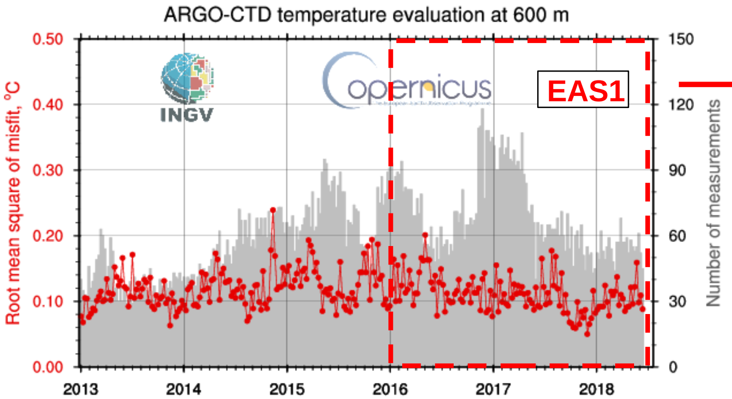
Time Series of Temperature RMS misfits at 30 & 600m depth

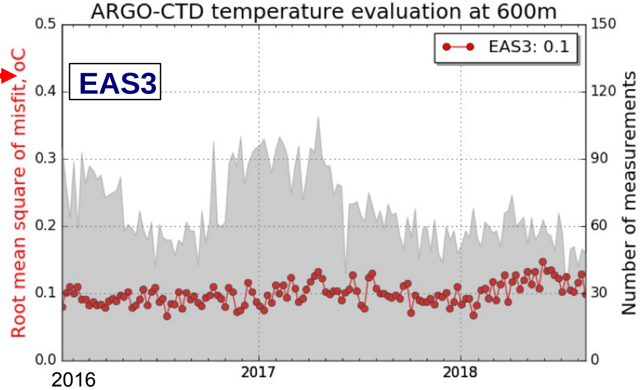
T RMS at 30m depth





T RMS at 600m depth

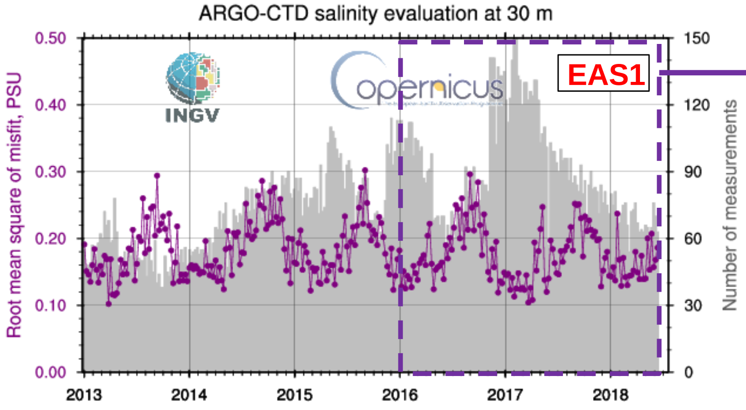


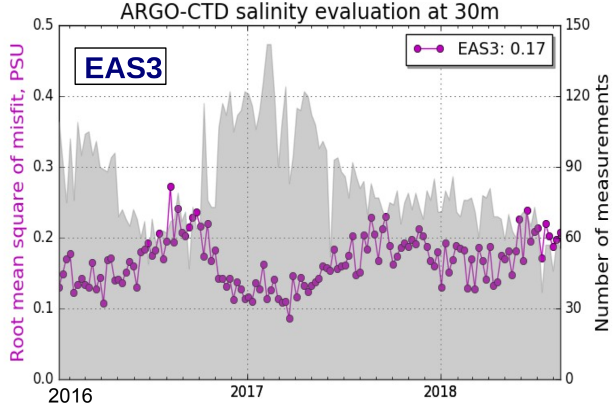


Quasi-Independent Validation: MISFITS

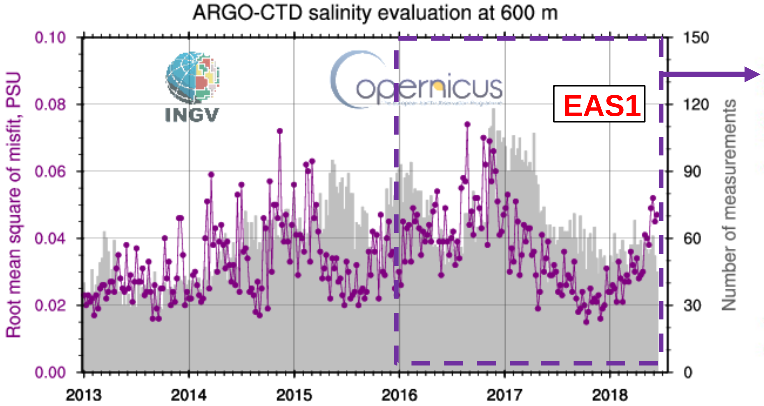
Time Series of Salinity RMS misfits at 30 & 600m depth

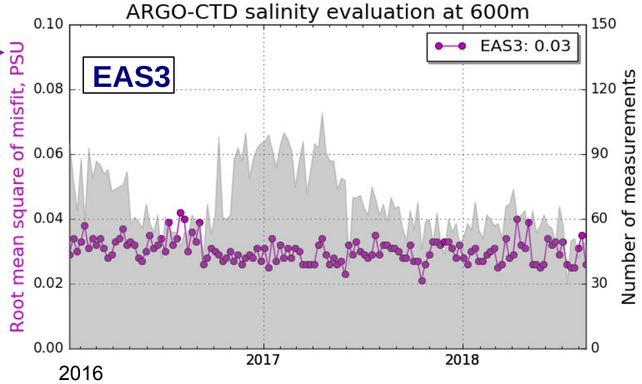
S RMS at 30m depth



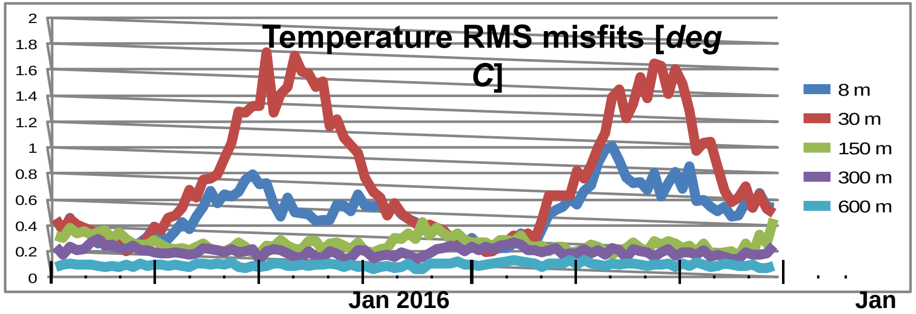


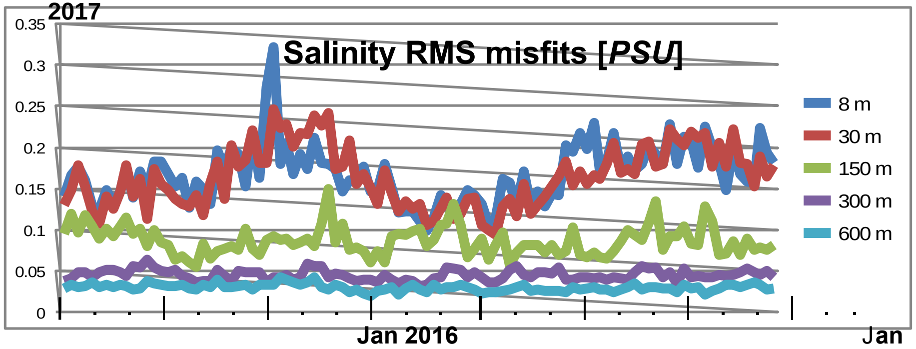
S RMS at 600m depth

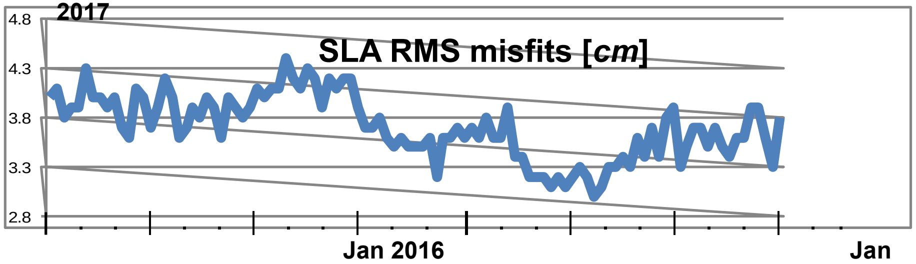


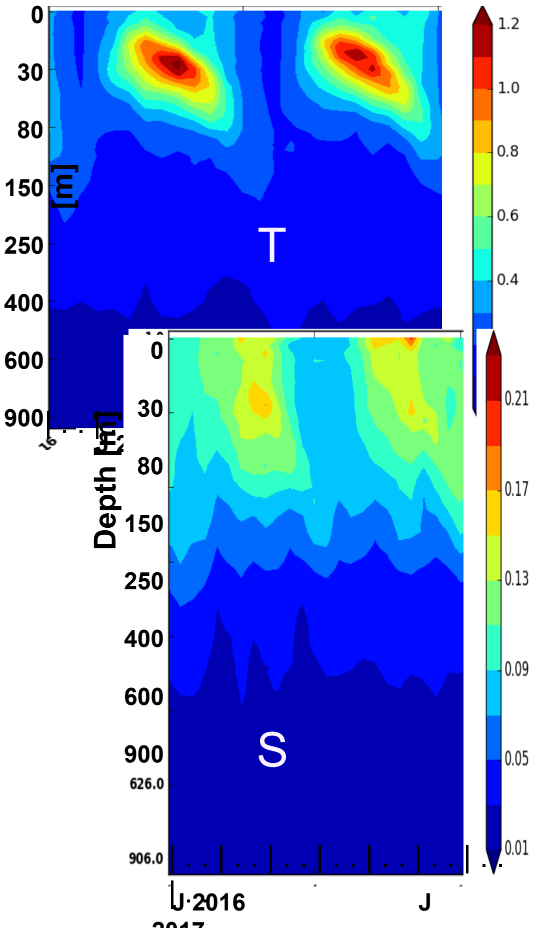


Quasi-Independent Validation: MISFITS









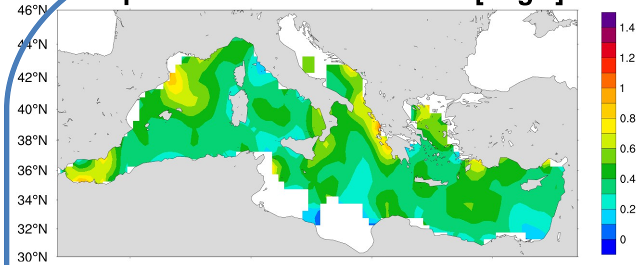
T & S error

- Larger error during summer
- Larger error at thermocline, that decreases at lower layers

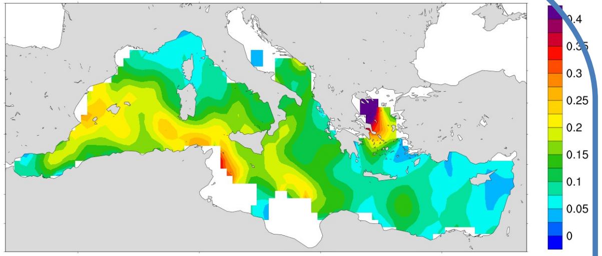
Quasi-Independent Validation: MISFITS

Spatial Variability of RMS misfits in 2016-2018

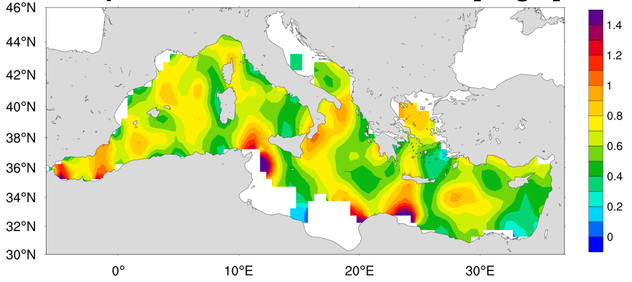
Temperature RMS mifits at 8m [*degC*]



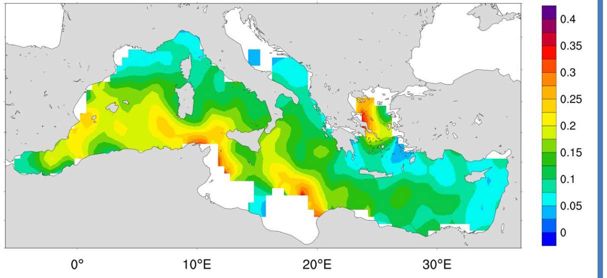
Salinity RMS mifits at 8m [*PSU*]



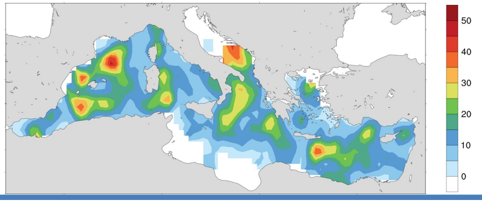
Temperature RMS mifits at 30m [*degC*]



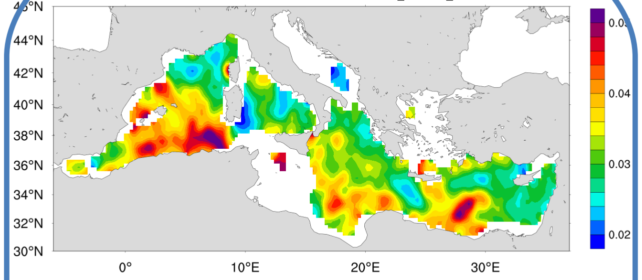
Salinity RMS mifits at 30m [*PSU*]



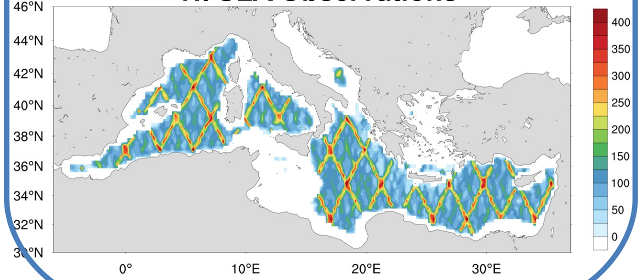
N. ARGO Observations



SLA RMS mifits [*cm*]

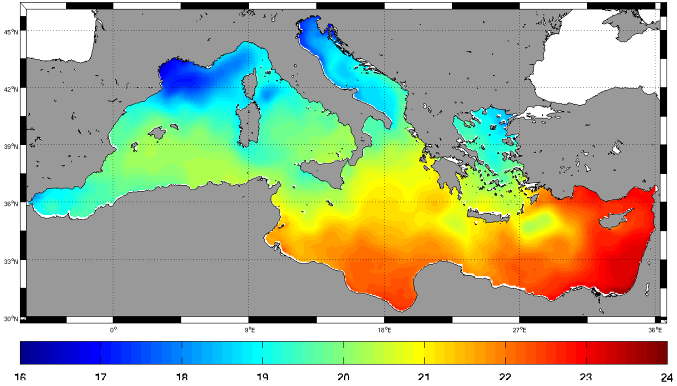


N. SLA Observations

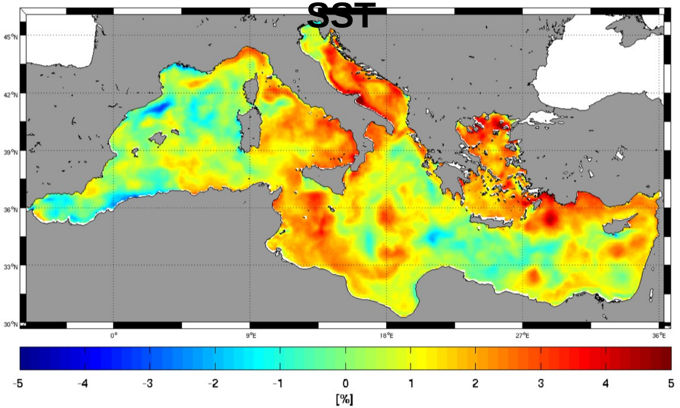


Quasi-Independent Validation SST: model VS. satellite L4 data

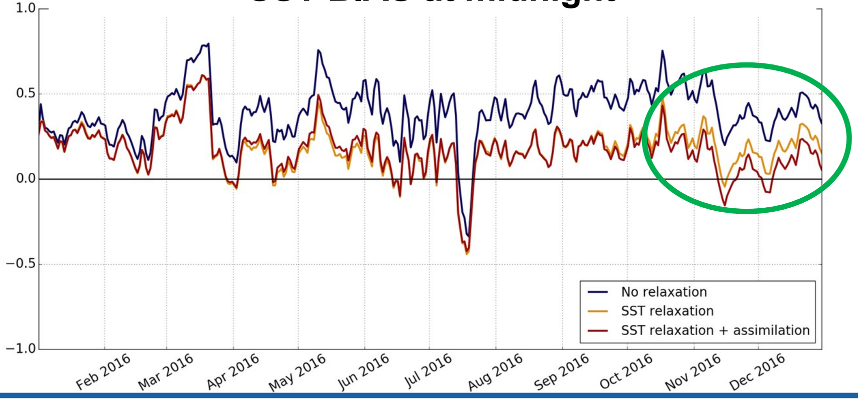
Satellite SST Annual Mean (2016)



Perc diff: (Model- Satellite SST)/Satellite SST



SST BIAS at midnight



SST is not assimilated but it is used to correct Heat fluxes by relaxation.

$$Q_{corrected} = Q_{forc} + \frac{dQdSST}{\rho C_p}(SST_{model} - SST_{observation})$$

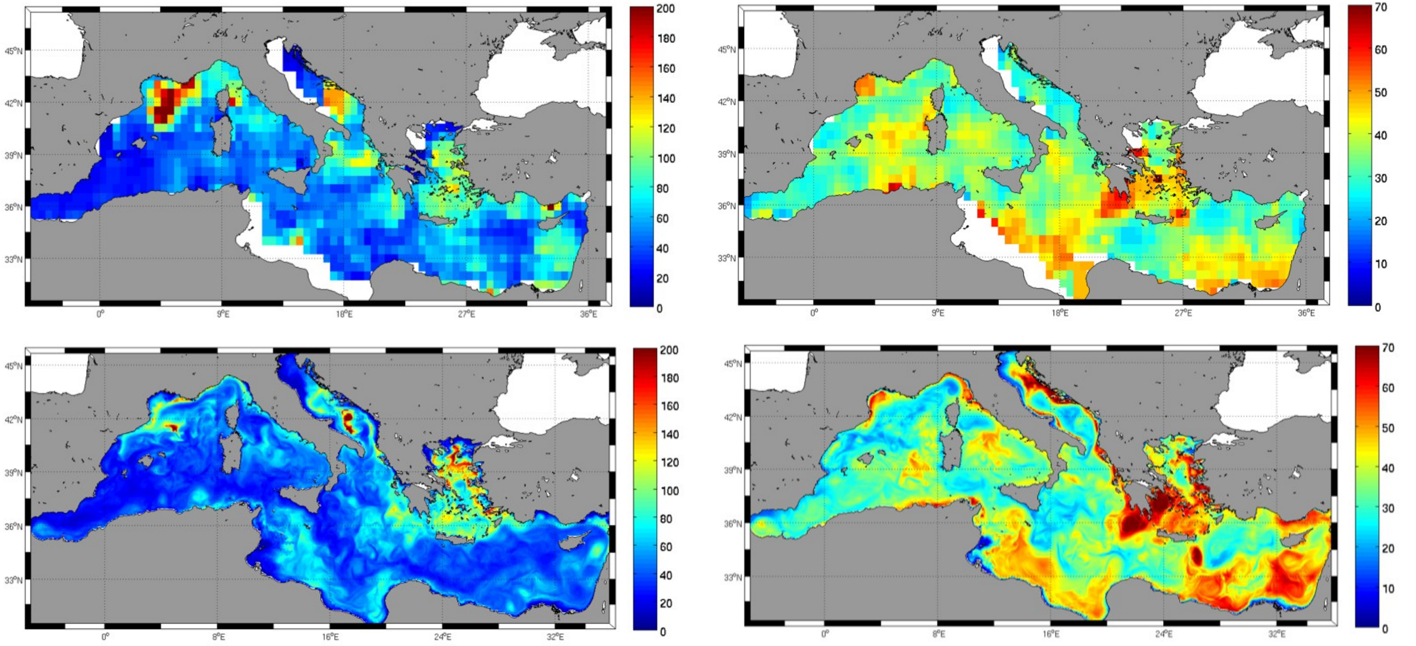
Data assimilation of ARGO and SLA improves
midnight SST values

Validation: Mixed Layer Depth

March | November

CLIMATOLOGY*

MODEL

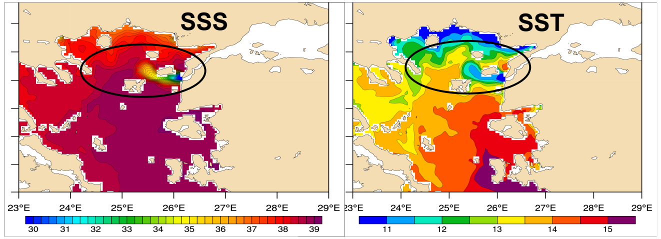


CLIMATOLOGY*: Houpert et al., 2015
Monthly gridded climatology produced using MBT, XBT, Profiling floats, Gliders, and ship-based CTD data from different database in the Med. 1969 - 2013

FUTURE UPGRADES

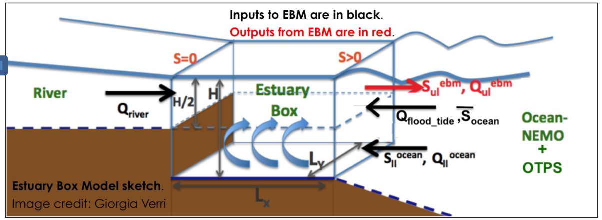
An upgraded analysis and forecasting system will enter in operation in July 2019 with the following improvements:

- **Dardanelles** strait inflow parameterized as an open boundary conditions; nesting through the GLO-MFC analysis and forecasting product
- **Improved SST relaxation**: move from a 24h relaxation to night time relaxation with gaussian coefficient



Foreseen major upgrades at end 2019 and 2020:

- Implementation of a 1-way coupled **Estuary Box Model** at river mouth to better represent river inflow and salinity
- Use of high frequency inter-annual **river run off and river forecast**, where available
- **Include tides** in the model
- Use a different **vertical mixing scheme**
- Improve **on-line coupling of NEMO with wave model** (enhanced vertical mixing)
- Data Assimilation: Include **assimilation of SST + Improvements** to account for Tides, new vertical mixing



SUMMARY - CONCLUSIONS

- The actual Mediterranean Sea Analysis and Forecast operational system has been presented highlighting major upgrades with previous version
- The increased resolution provides better prediction of fluxes at Gibraltar strait, allows to resolve the Messina Strait circulation
- The increased n. of river inputs provides better representation of surface salinity next to river mouths as well as the volume salinity in the Mediterranean Sea
- The model validation assessment is performed regularly and shows:
  - improvements in terms of Temperature and Salinity with respect to the previous system
  - the model ability to correctly represent the time and spatial variability of the major physical parameters
- A continuous upgrade of the system is foreseen in order to improve the quality of the analysis and forecasting system and provide state of the art product to the users

Thanks

cmcc
Centro Euro-Mediterraneo
sui Cambiamenti Climatici