OceanPredict '19
GODAE OceanView Symposium | 6-10 May 2019 Halifax, Canada
Advancing the science and application of ocean predictions

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

Clementi Emanuela[1], Pistoia Jenny[1], Delrosso Damiano[2], Escudier Romain[1], Drudi Massimiliano[1], Grandi Alessandro[1], Lyubartsev Vladyslav[1], Ciliberti Stefania[1], Pinardi Nadia[3], Masina Simona[1], Coppini Giovanni[1]

(1) CMCC, Euro-Mediterranean Centre on Climate Change, Italy
(2) INGV, National Institute of Geophysics and Volcanology, Italy
(3) Department of Physics and Astronomy, University of Bologna, Italy

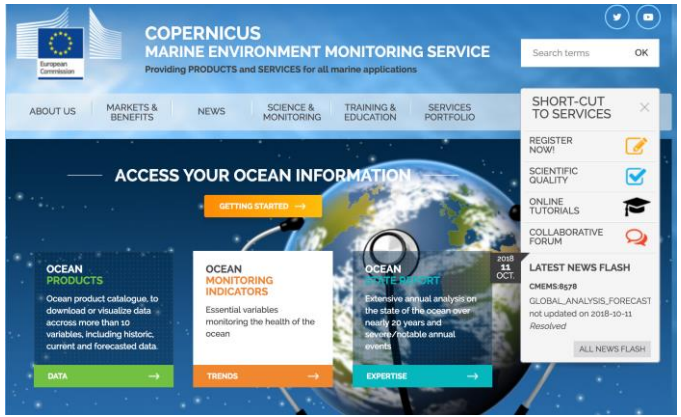
OUTLINE

- 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/



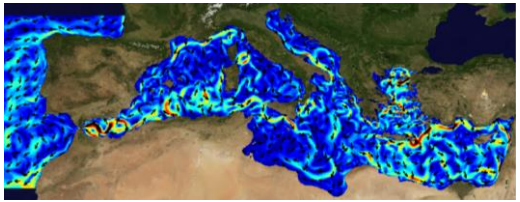
2 CMEMS Med-PHY Products

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

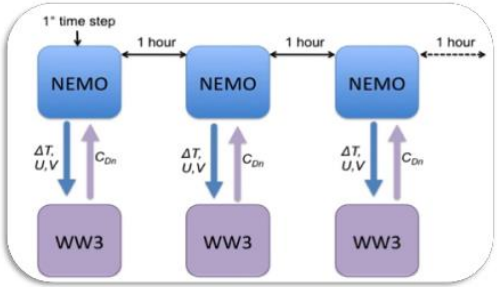
Med-Physics Analysis and Forecast system

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

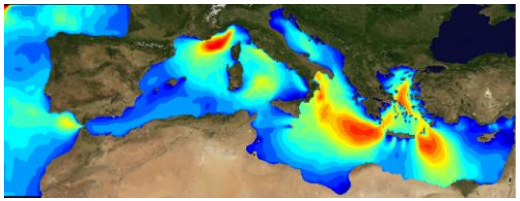


Hor. Res. = 1/24º (~4.5 km)
Vert. Res. = 141 z* vertical levels with partial cells

2-way
hourly
coupling



Wave model
WaweWatch-III (WW3) v3.14



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

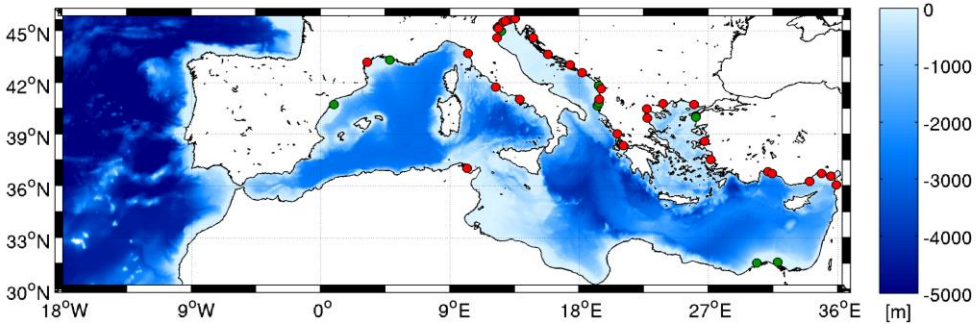
The two-way coupling consists of inputting:
Surface currents (for wave refraction) and **air-sea temperature difference** (for wind speed correction)
From NEMO to the wave model and
providing the **neutral surface drag coefficient** from waves which is used to compute the wind stress in NEMO

Med-Currents Analysis and Forecast system: Forcings

ECMWF 1/8° 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 with annual mean discharge > 50 m^3/s using climatological monthly mean seasonal cycle values
The **Dardanelles strait** 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

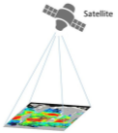
Model solutions are corrected by the data assimilation

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

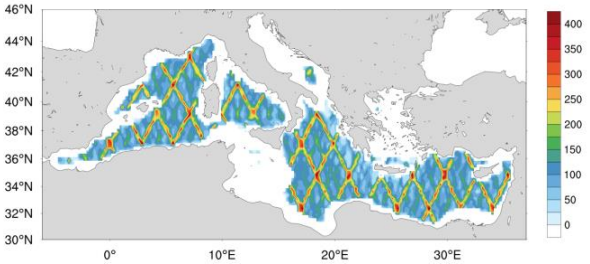
- Jason 2/2N, 3
- Cryosat2
- Saral/AltiKa
- Sentinel3A



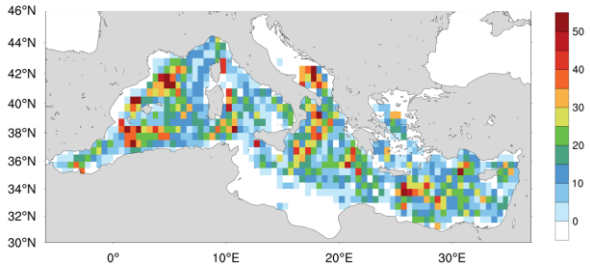
Vertical profiles of Temperature and Salinity from CMEMS InSitu TAC:

Argo XBT

SLA data assimilated in 2016-2017



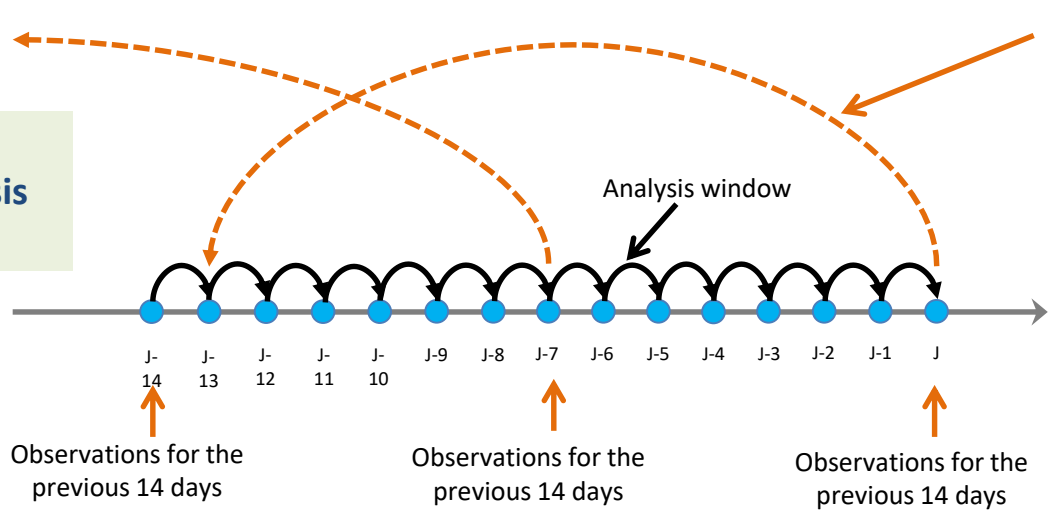
ARGO data assimilated in 2016-2017



Non-solar heat flux correction is achieved through satellite L4 **SST nudging**

Med-Currents Analysis and Forecast system: Data Assimilation

The data are assimilated weekly with a daily analysis window



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 [m^2/s]	**vertical background viscosity / diffusivity values**	1.2e-6 / 1.0e-7 [m^2/s]
-6.e8 / -1.e9 [m^4/s]	**horizontal bilaplacian eddy diffusivity / viscosity**	-1.2e8 / -2.e8 [m^4/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

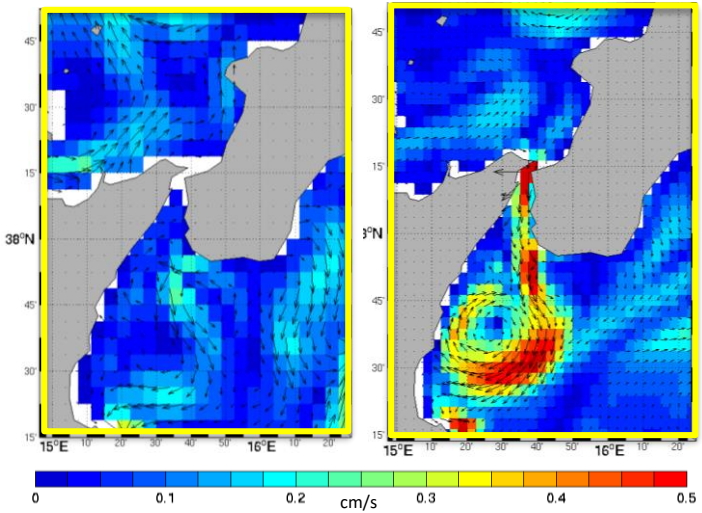
- Air-sea fluxes: MFS bulk formulae described in Pettenuzzo et al. (2010)
- Advection scheme for active tracers: mixed up-stream/MUSCL
- Vertical diffusion and viscosity terms: Function of the Richardson number as parameterized by Pacanowsky and Philander (1981)

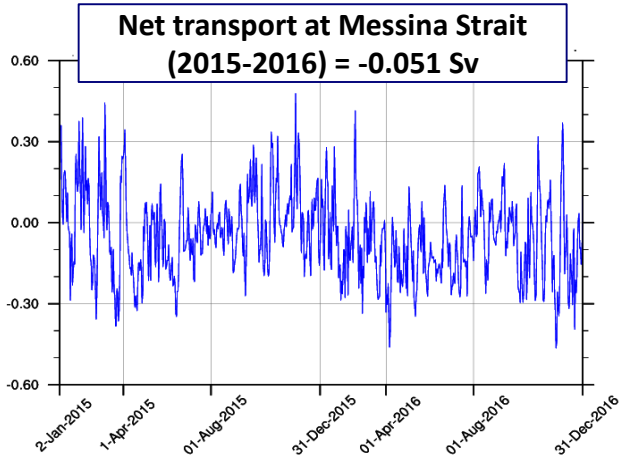
Impacts due to increased resolution

MESSINA STRAIT

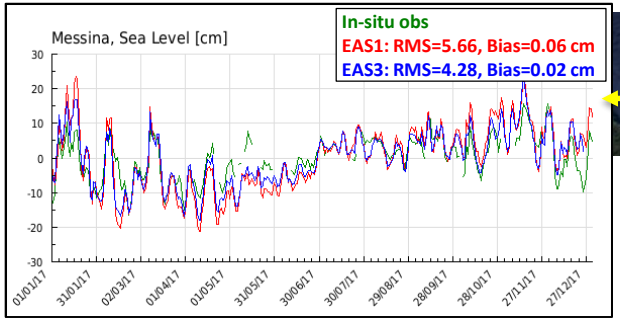
EAS1 (1/16º)

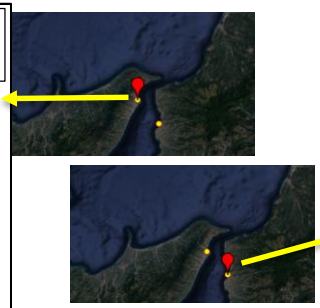
EAS3 (1/24º)

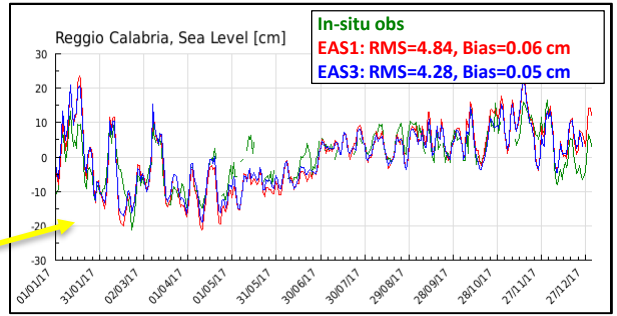




Sea Level comparison



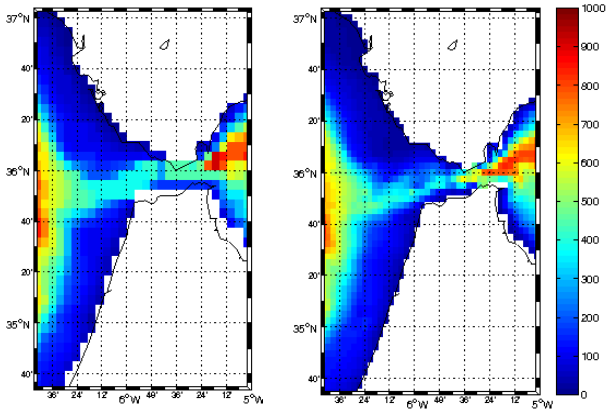


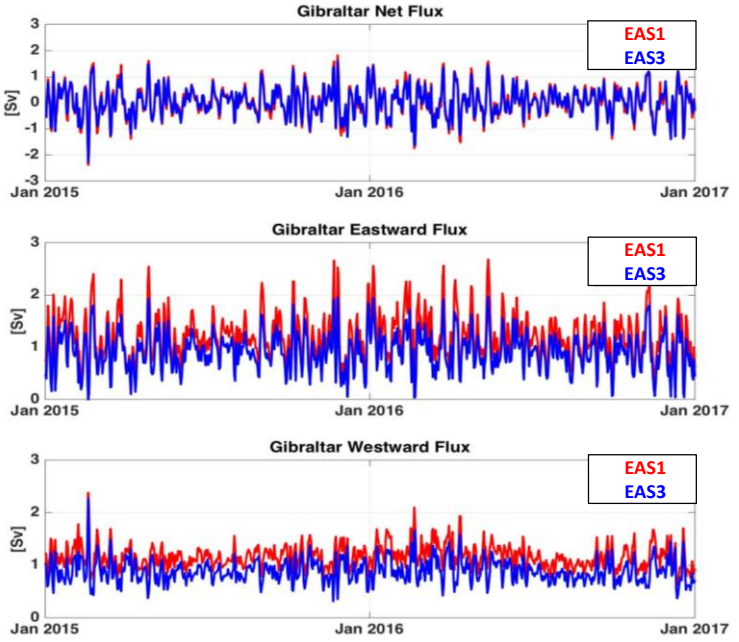


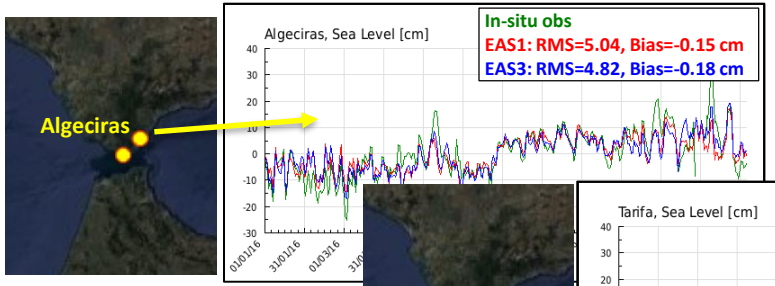
Impacts due to increased resolution

EAS1 (1/16º)

EAS3 (1/24º)







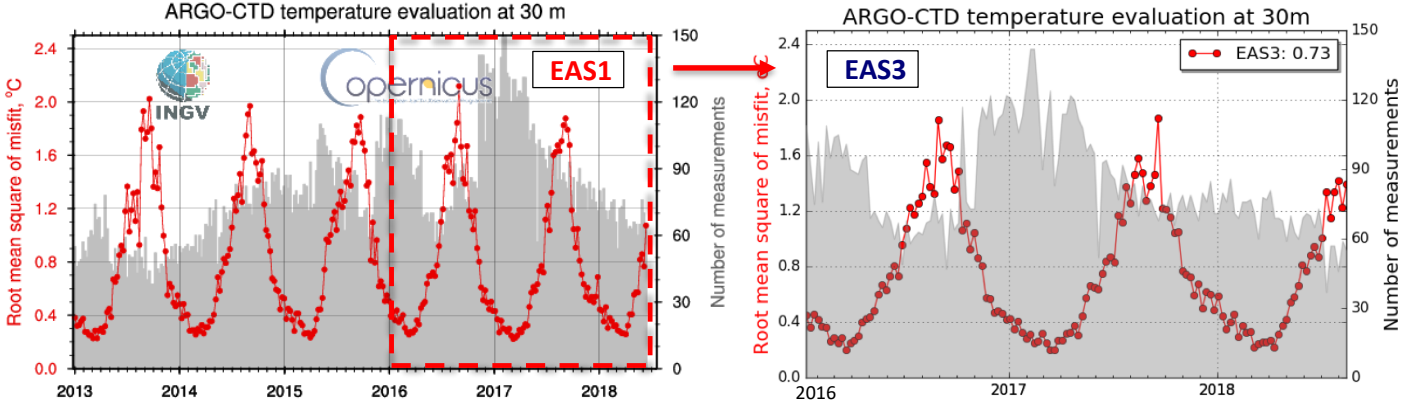
Sea Level comparison

Gibraltar Mean Flux *[Sv]*	EAS1	EAS3	Soto-Navarro et al., 2010
Net	0.032	0.04	0.038 ± 0.007
Eastward	1.20	0.907	0.81 ± 0.06
Westward	1.16	0.867	0.78 ± 0.05

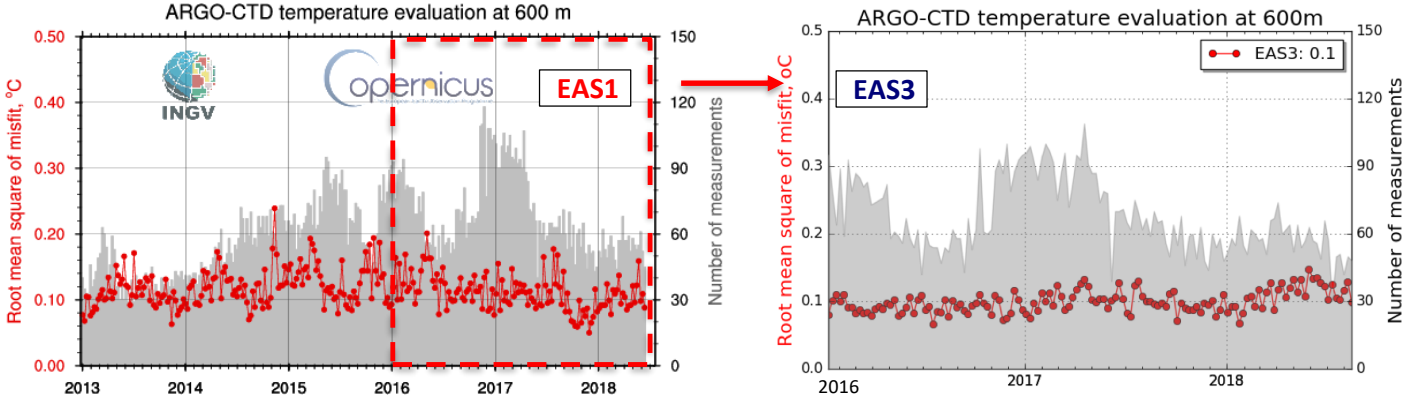
Quasi-Independent Validation: MISFITS

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

T RMS at 30m depth



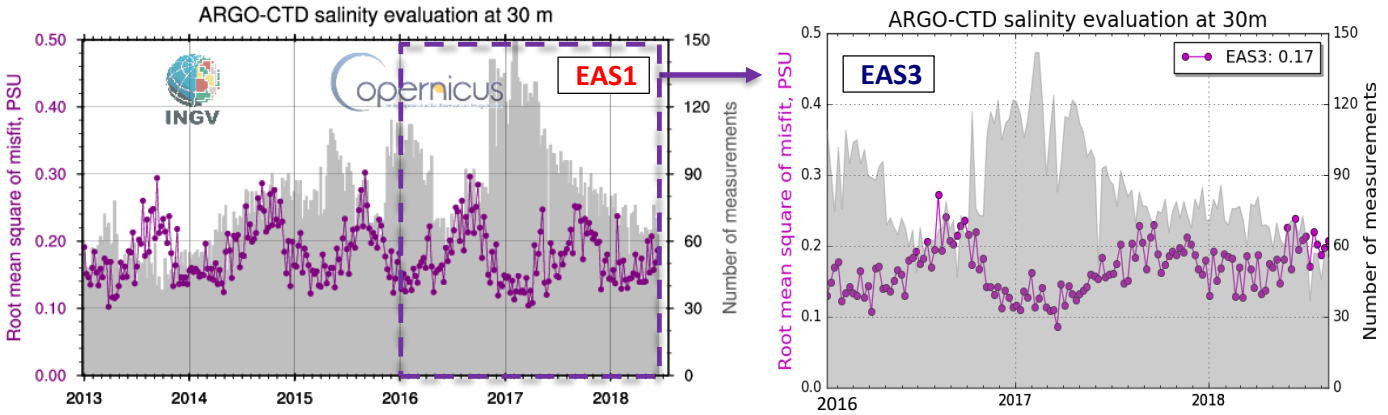
T RMS at 600m depth



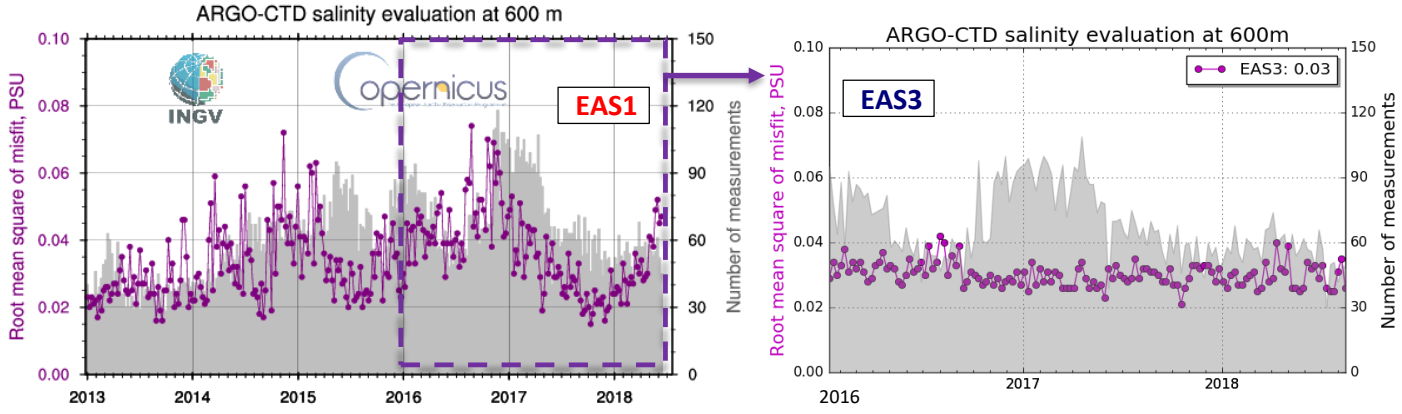
Quasi-Independent Validation: MISFITS

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

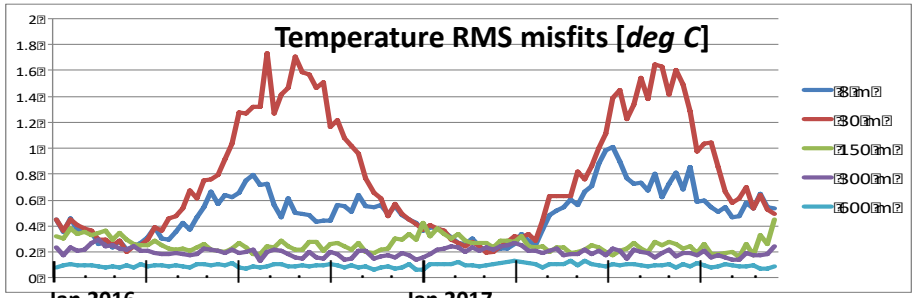
S RMS at 30m depth

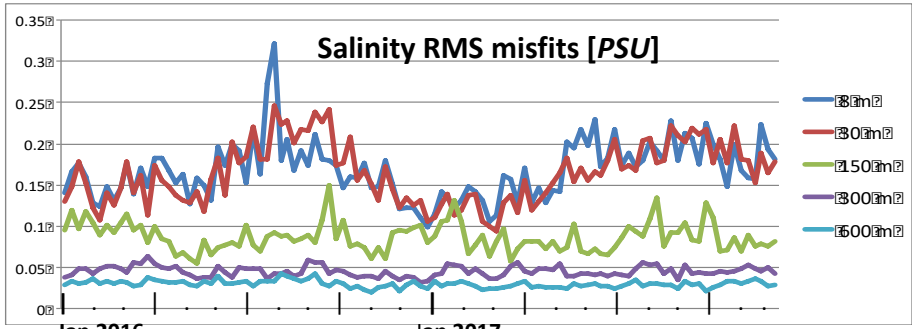


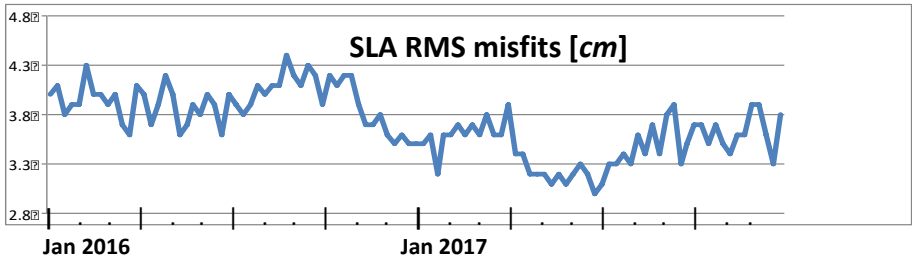
S RMS at 600m depth

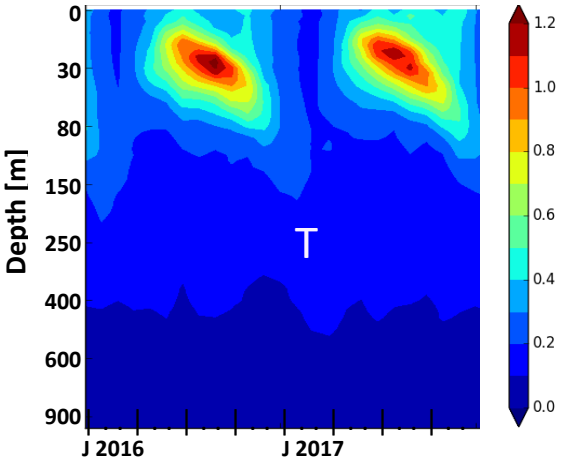


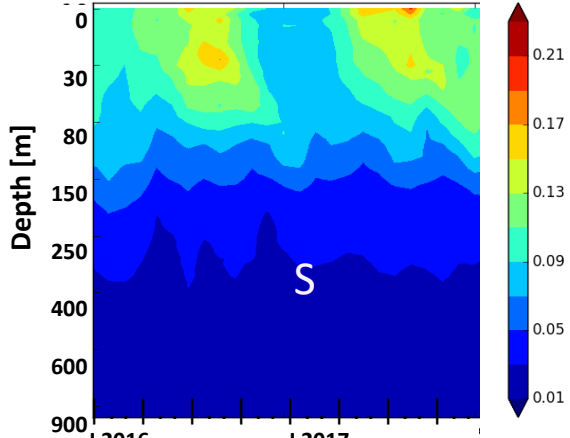
Quasi-Independent Validation: MISFITS











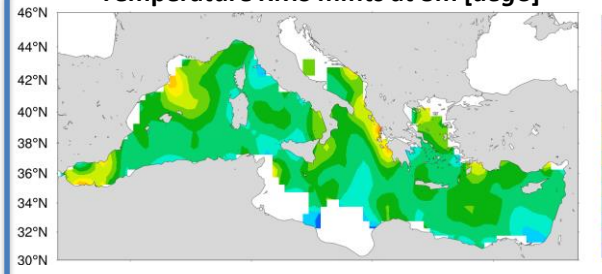
T & S error

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

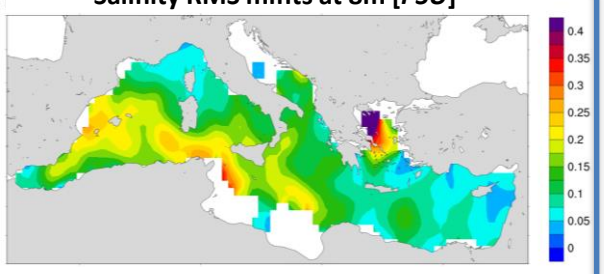
Quasi-Independent Validation: MISFITS

Spatial Variability of RMS misfits in 2016-2018

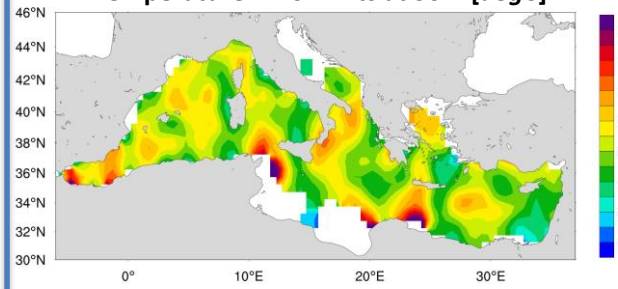
Temperature RMS mifits at 8m [*degC*]



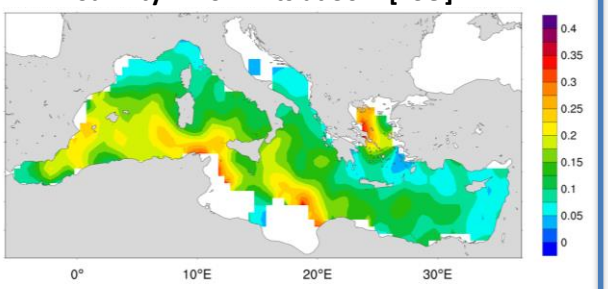
Salinity RMS mifits at 8m [*PSU*]



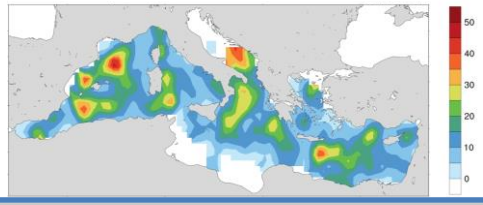
Temperature RMS mifits at 30m [*degC*]



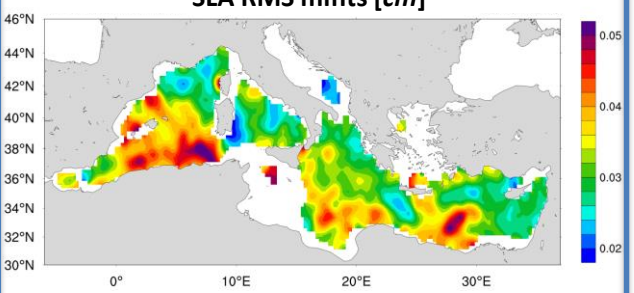
Salinity RMS mifits at 30m [*PSU*]



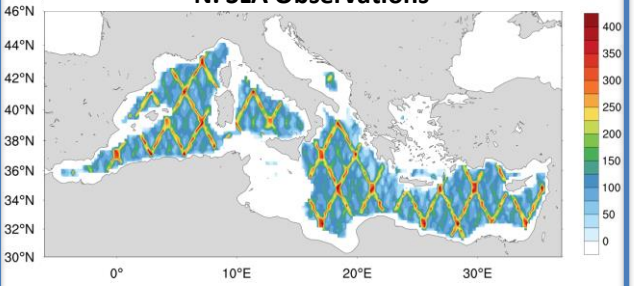
N. ARGO Observations



SLA RMS mifits [*cm*]

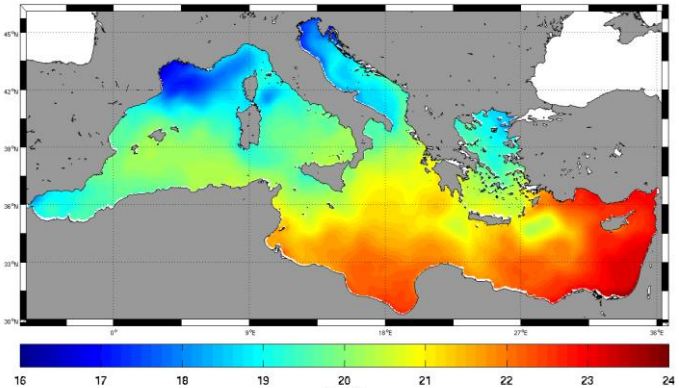


N. SLA Observations

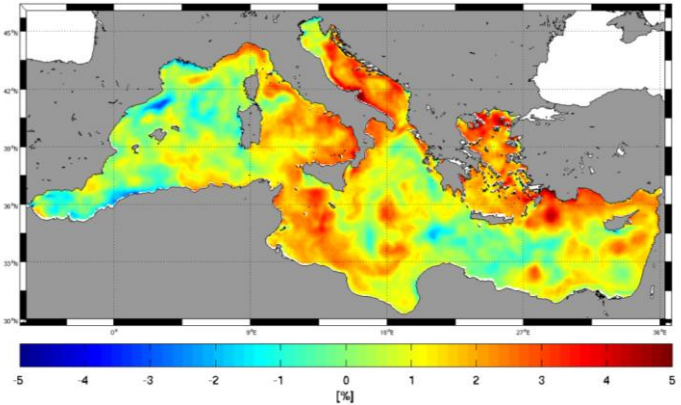


Quasi-Independent Validation SST: model VS. satellite L4 data

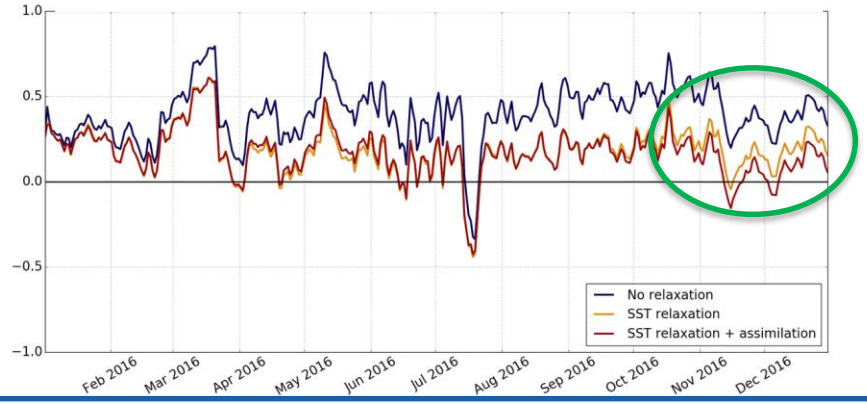
Satellite SST Annual Mean (2016)



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



SST BIAS at midnight

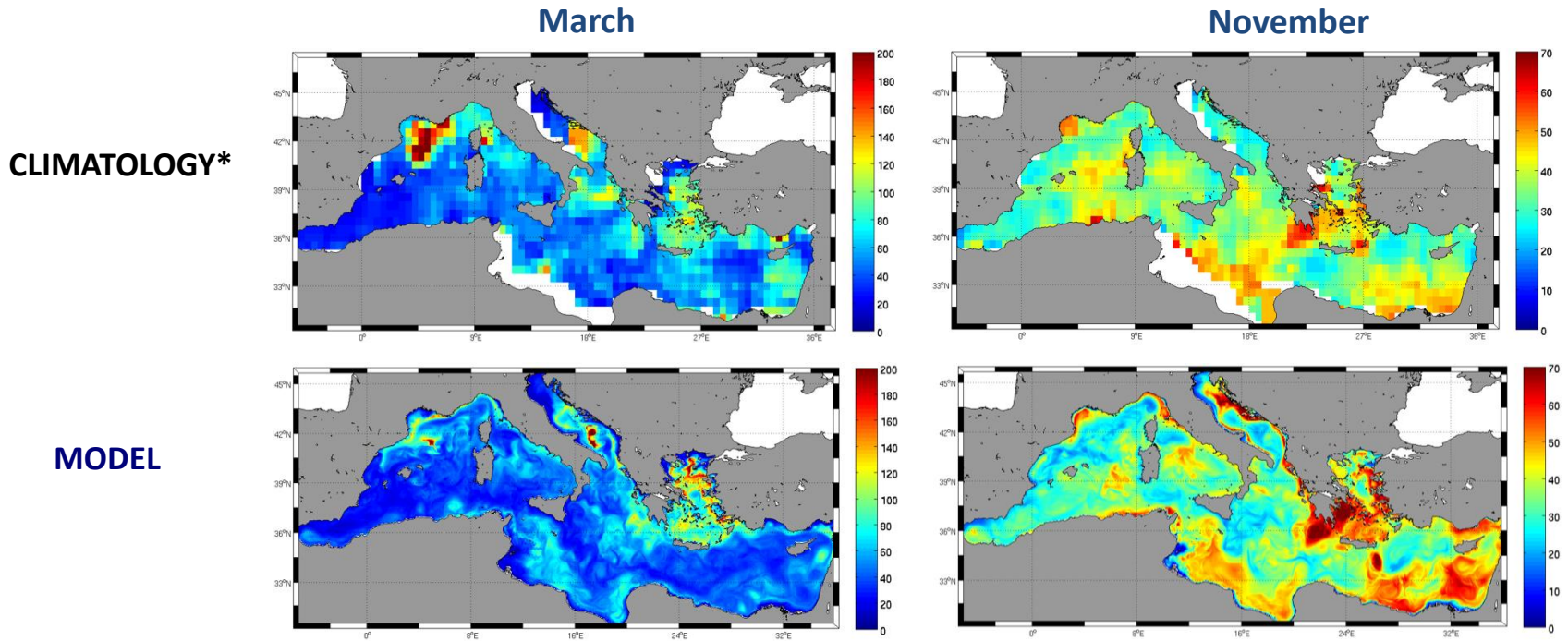


SST is not assimilated but it is used to correct Heat fluxes by relaxation.

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

Data assimilation of ARGO and SLA improves midnight SST values

Validation: Mixed Layer Depth



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

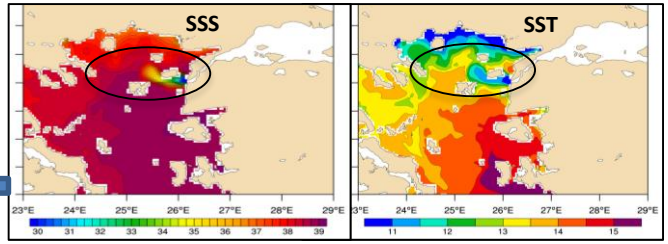
An upgraded analysis and forecasting system will enter in operation in July 2019 with the following improvements:

- **Dardanelles** strait inflow parameterized as an open boundary conditions; nesting through the GLO-MFC analysis and forecasting product

  → Provides improvements in North Aegean Sea

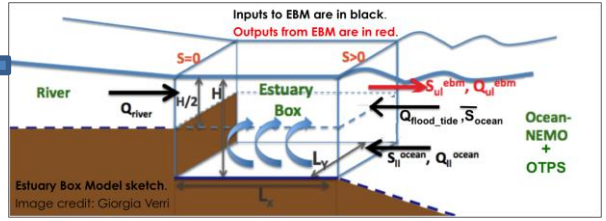
- **Improved SST relaxation**: move from a 24h relaxation to night time relaxation with gaussian coefficient

  → Increase consistency with observations



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