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

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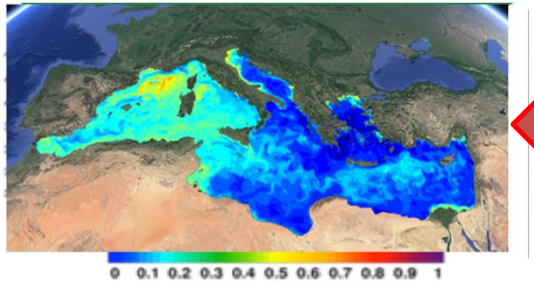
OUTLINE

- Med-MFC overview in the CMEMS framework
- Med-Physics Analysis and Forecast system description
  - Main differences between actual and previous modeling system
  - 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-MFC overview in the CMEMS framework

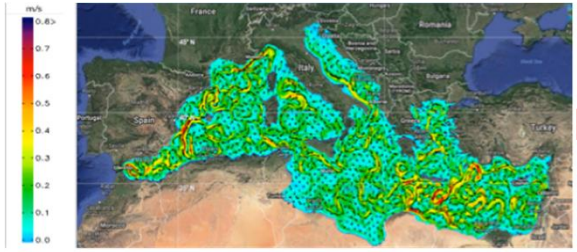
CMEMS Med-MFC is one of the 7 MFC of CMEMS
A consortium of 3 research institutes:
CMCC (Leader of the consortium and responsible for the Physical product)
OGS (Responsible for the Biogeochemical product)
HCMR (Responsible for the Wave product)

Med-Biogeochemistry PU

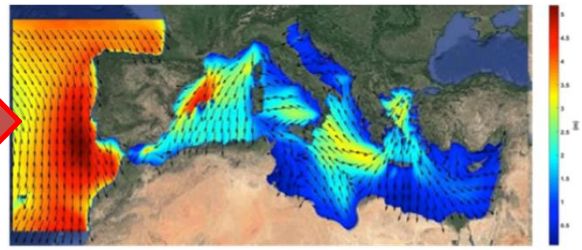


Med-Physics PU

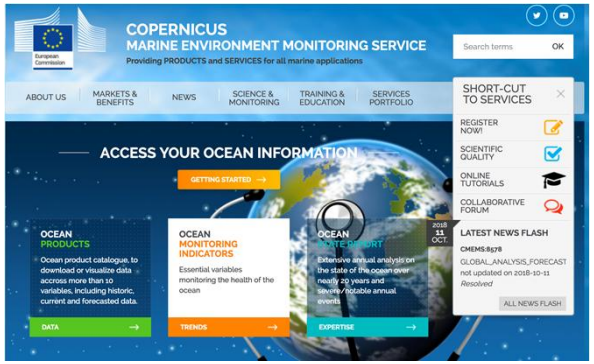
cmcc
Centro Euro-Mediterraneo sui Cambiamenti Climatici



Med-Wave PU



Med-Physics Products delivered



http://marine.copernicus.eu/

Analyses and Forecast

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

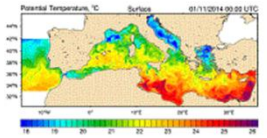
Hourly + Daily + Monthly mean

MEDITERRANEAN SEA PHYSICS ANALYSIS AND FORECAST

Numerical-model, Temperature, Salinity, Currents, Sea-level, Near-real-time, Forecast, Mediterranean-sea

MEDSEA_ANALYSIS_FORECAST_PHY_006_013

The physical component of the Mediterranean Forecasting System (Med-currents) is a coupled hydrodynamic-wave model implemented over the whole Mediterranean Basin. The model horizontal grid resolution is 1/16° (ca. 6-7 km) and has 72 unevenly spaced vertical levels.
The hydrodynamics are supplied by the Nucleous for European Modelling of the Ocean (NEMO) while the wave component is provided by WaveWatch-III. The model solutions are corrected by the variational assimilation (based on a 3DVAR scheme) of temperature and salinity vertical profiles and along track satellite Sea Level Anomaly observations.



MORE INFO ADD TO CART

PHY Reanalysis (1987-2016)

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

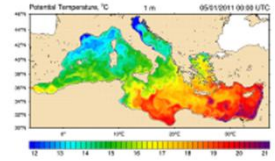
Daily + Monthly mean

MEDITERRANEAN SEA PHYSICS REANALYSIS (1987- 2016)

Numerical-model, Currents, Sea-level, Temperature, Salinity, Multi-year, Mediterranean-sea

MEDSEA_REANALYSIS_PHYS_006_004

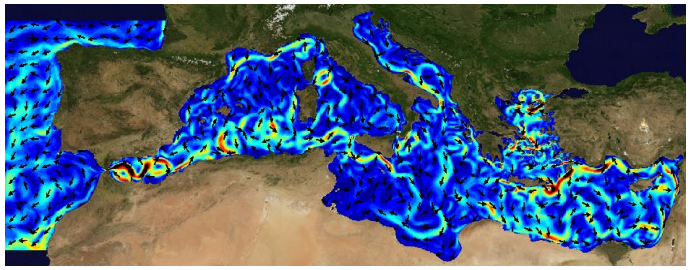
The Mediterranean Forecasting System, physical reanalysis component, is a hydrodynamic model, supplied by the Nucleous for European Modelling of the Ocean (NEMO), with a variational data assimilation scheme (OceanVAR) for temperature and salinity vertical profiles and satellite Sea Level Anomaly along track data.The model horizontal grid resolution is 1/16° (ca. 6-7 km) and the unevenly spaced vertical levels are 72.



MORE INFO ADD TO CART

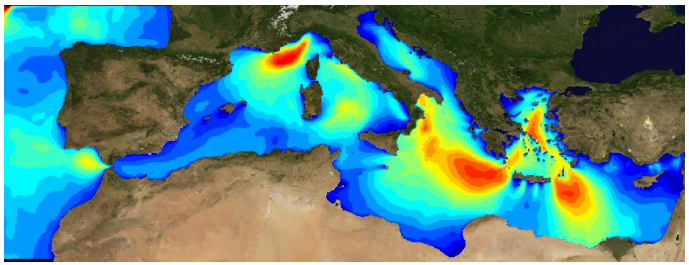
Med-Physics Analysis and Forecast system

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

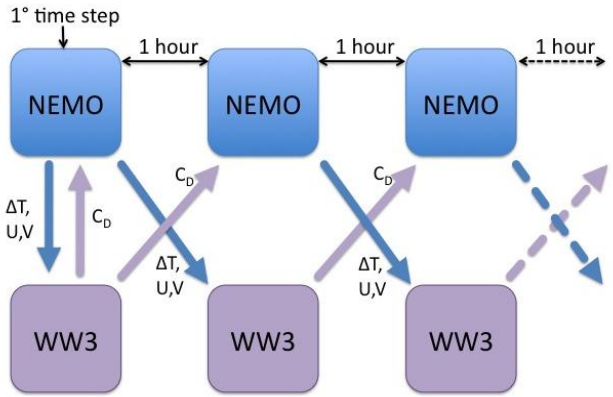


2-way
hourly
coupling

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

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

Med-Currents Analysis and Forecast system description

Main differences between actual and previous modeling system

Previous system EAS1		New 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]
300s	Time step	240s
SDN Clim T/S	Initaial Conditions	WOA-V2 Winter Clim T/S
From modified DBDB1 1min	Bathymetry	From modified GEBCO 30arc-sec
Dobricic and Pinardi (2008)	Data Assimilaton	Storto et al. (2015) adapted for the Mediterranean Sea

Common parameterizations

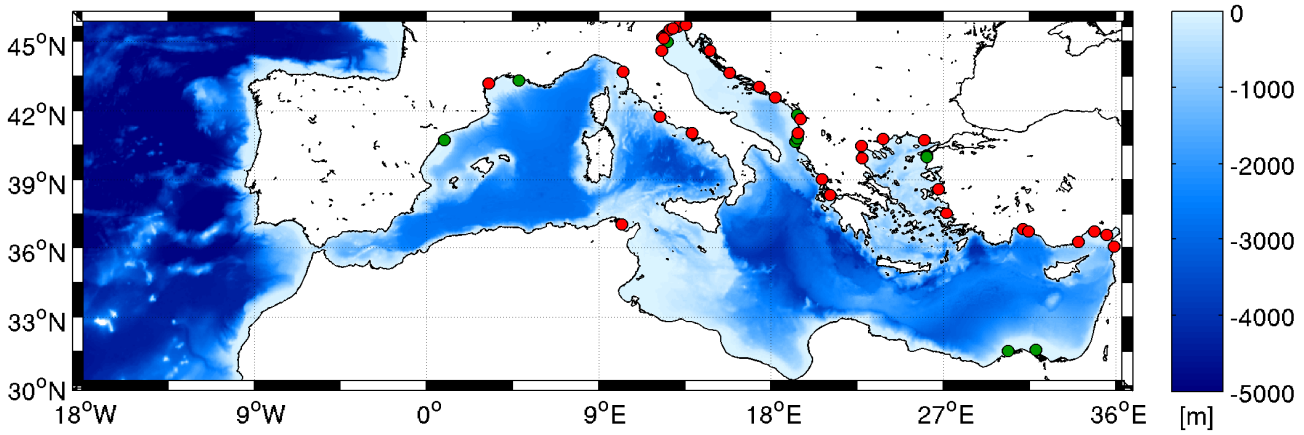
- Air-sea fluxes: MFS bulk formulae described in Pettenuzzo et al. (2010)
- Advection scheme for active tracers: mixed up-stream/MUSCL
- Vertical diffusion and viscosity terms: Function of the Richardson number as parameterized by Pacanowsky and Philander (1981)

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 nest 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 m^3/s using climatological monthly mean seasonal cycle values from PERSEUS project dataset
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

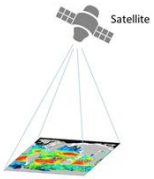
Model solutions are corrected by the data assimilation

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



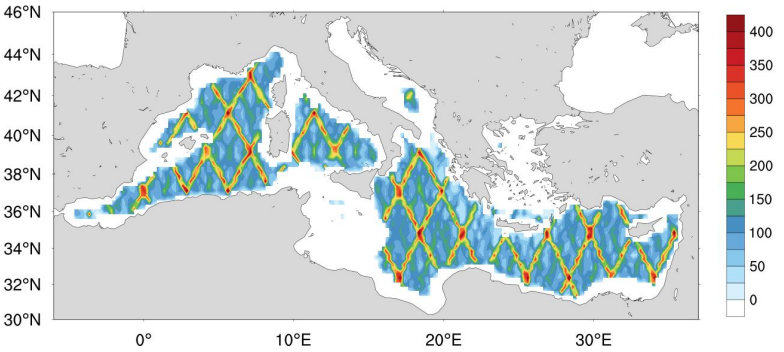
Vertical profiles of Temperature and Salinity from CMEMS InSitu TAC:

Argo

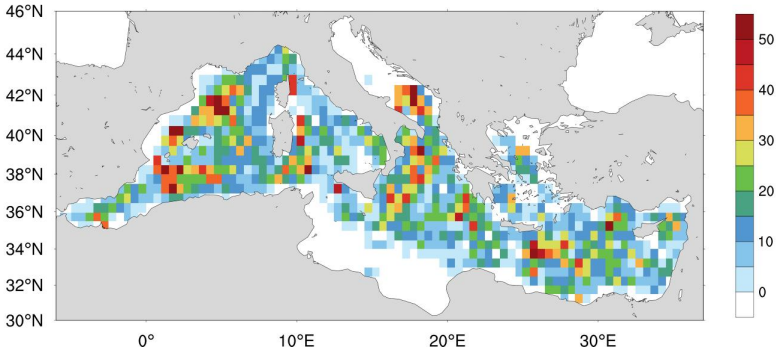
XBT

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

SLA data assimilated in 2016-2017

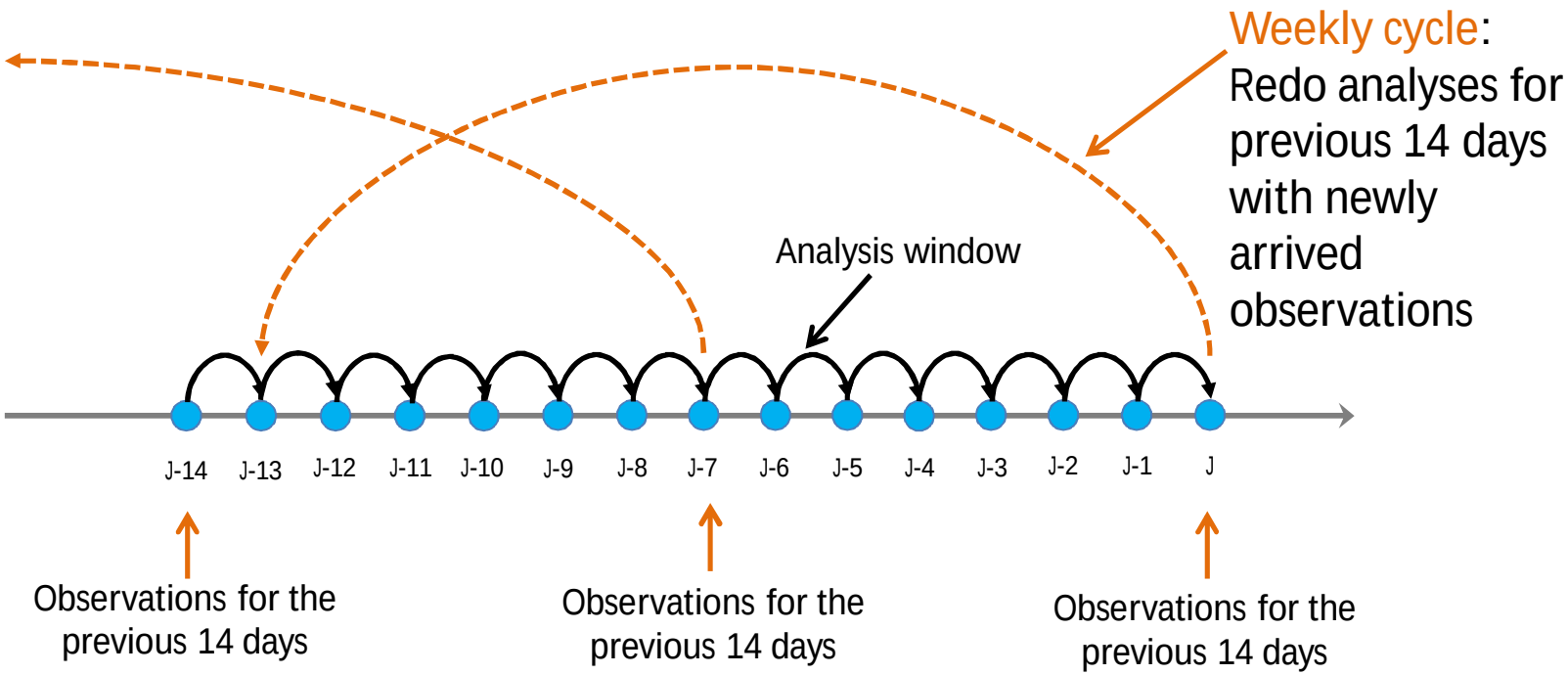


ARGO data assimilated in 2016-2017



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: satellite data (SLA) + in situ data (ARGO, XBT, CTD)

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

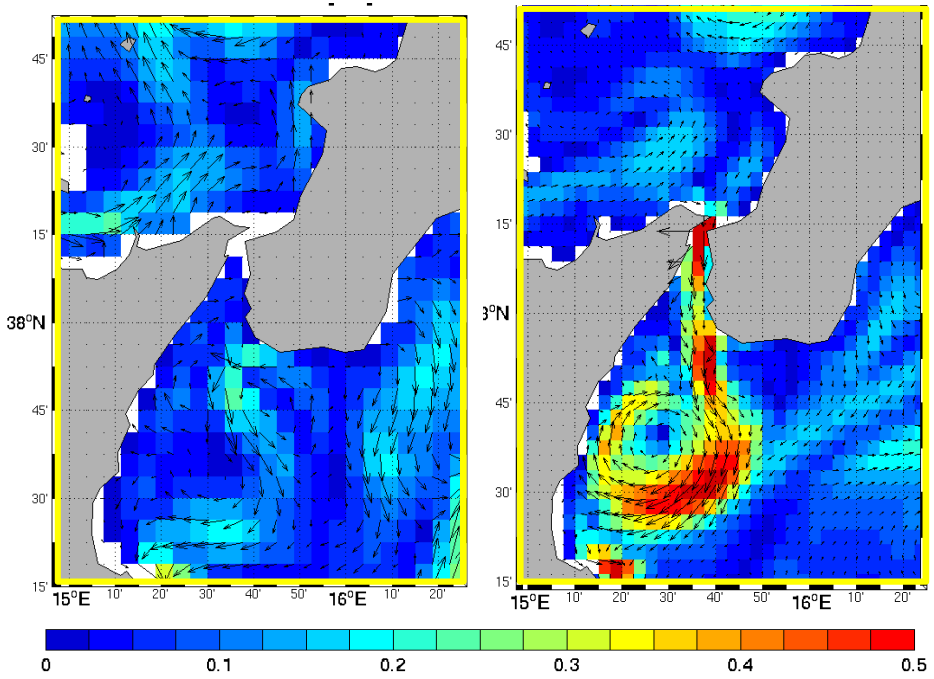
FORECAST: Computed for next 10 days forcing the numerical model with ECMWF forecast fields

Impacts due to increased resolution

MESSINA STRAIT

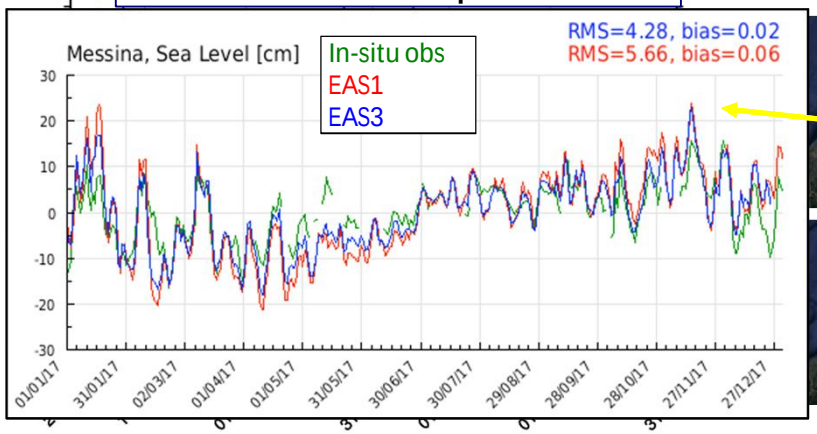
Surf Currents
EAS1 (1/16º)

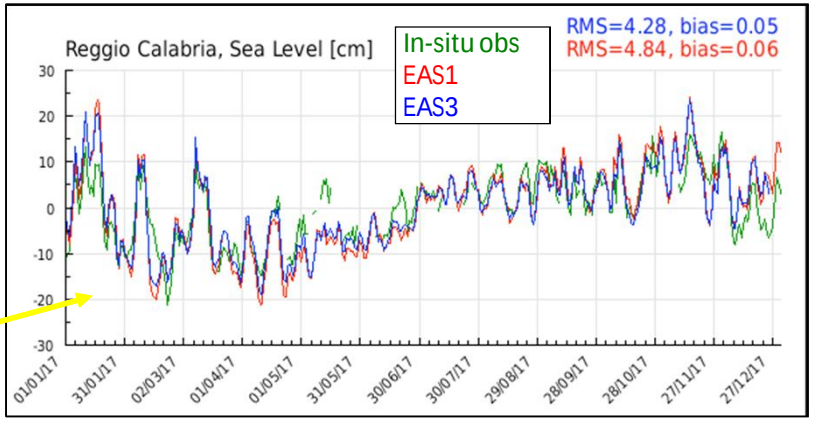
Surf Currents
EAS3 (1/24º)



Net transport at Messina Strait
(2015-2016) = -0.051 Sv

Sea Level comparison

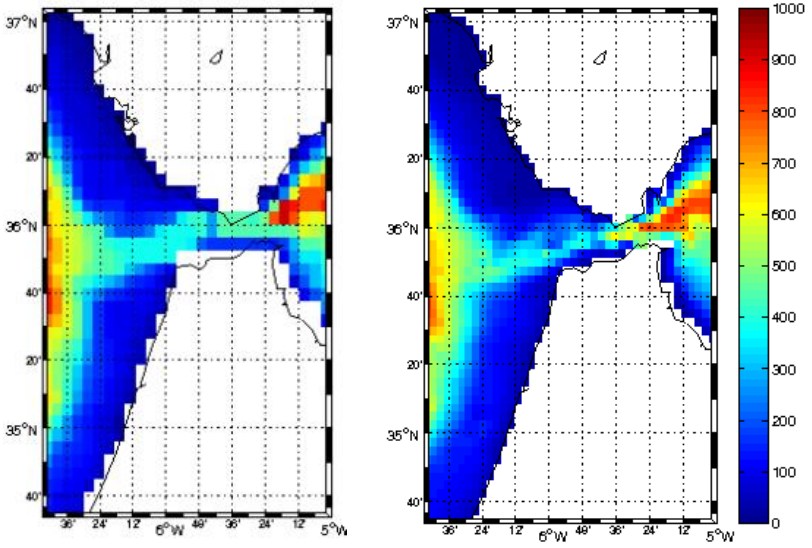


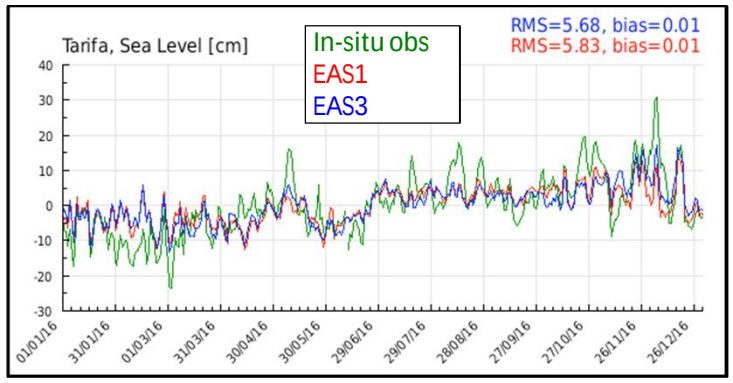


Impacts due to increased resolution

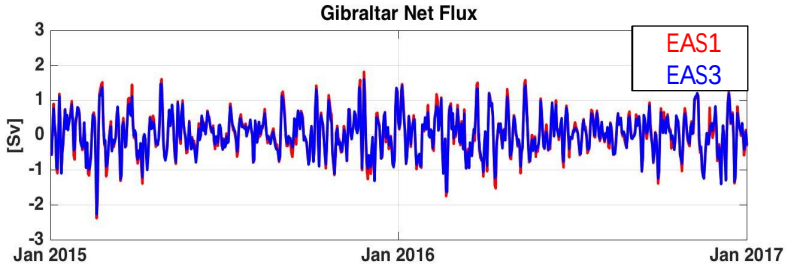
Bathymetry at Gibraltar Strait

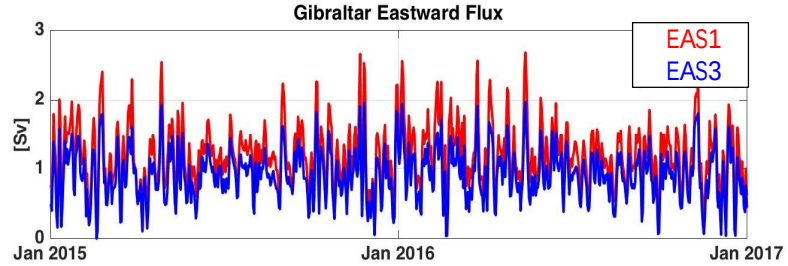
EAS1(1/16º) EAS3(1/24º)

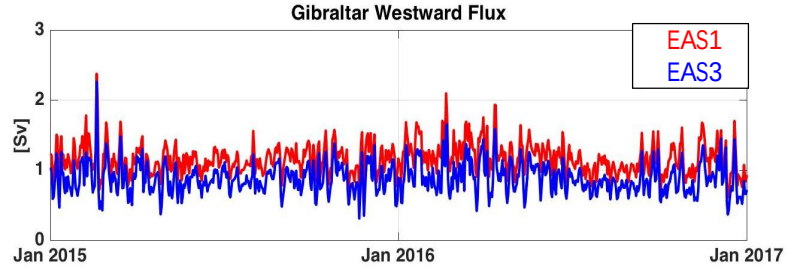




Sea Level (2016-2017)	EAS1	EAS3
RMS Algeciras [*cm*]	5.66	5.08
RMS Tarifa [*cm*]	6.06	5.80



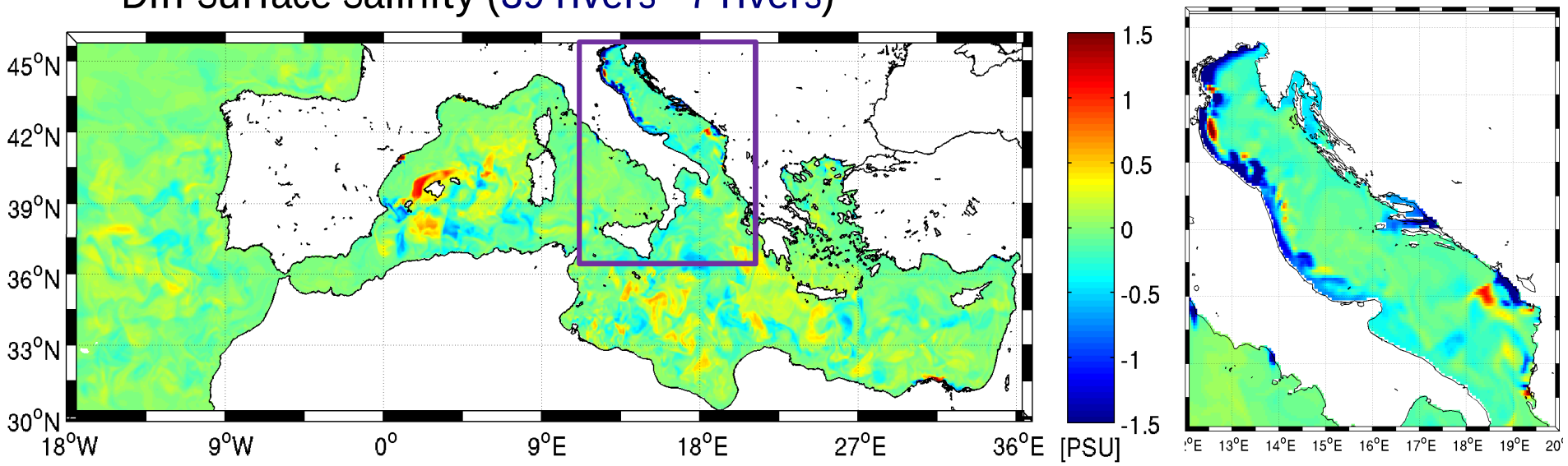




Gibraltar Mean Flux	EAS1	EAS3	Soto-Navarro et al., 2010
Net *[Sv]*	0.032	0.04	0.038 ± 0.007
Eastward *[Sv]*	1.20	0.907	0.81 ± 0.06
Westward *[Sv]*	1.16	0.867	0.78 ± 0.05

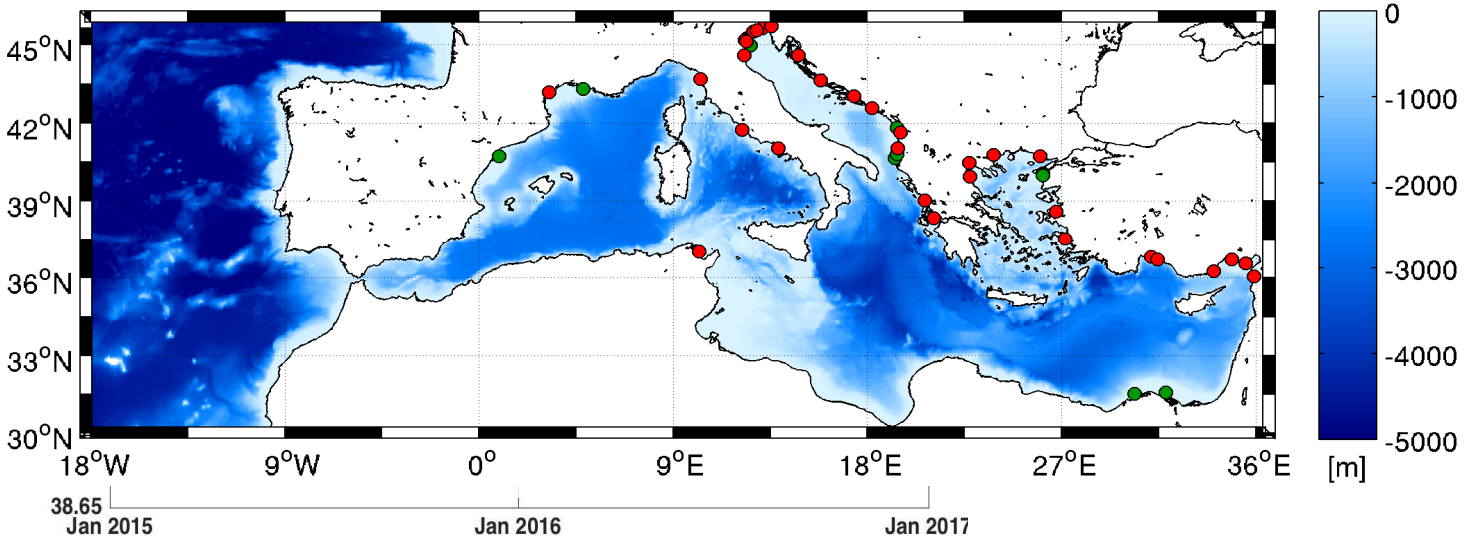
Impacts due to increased n. of rivers

Diff Surface Salinity (39 rivers –7 rivers)



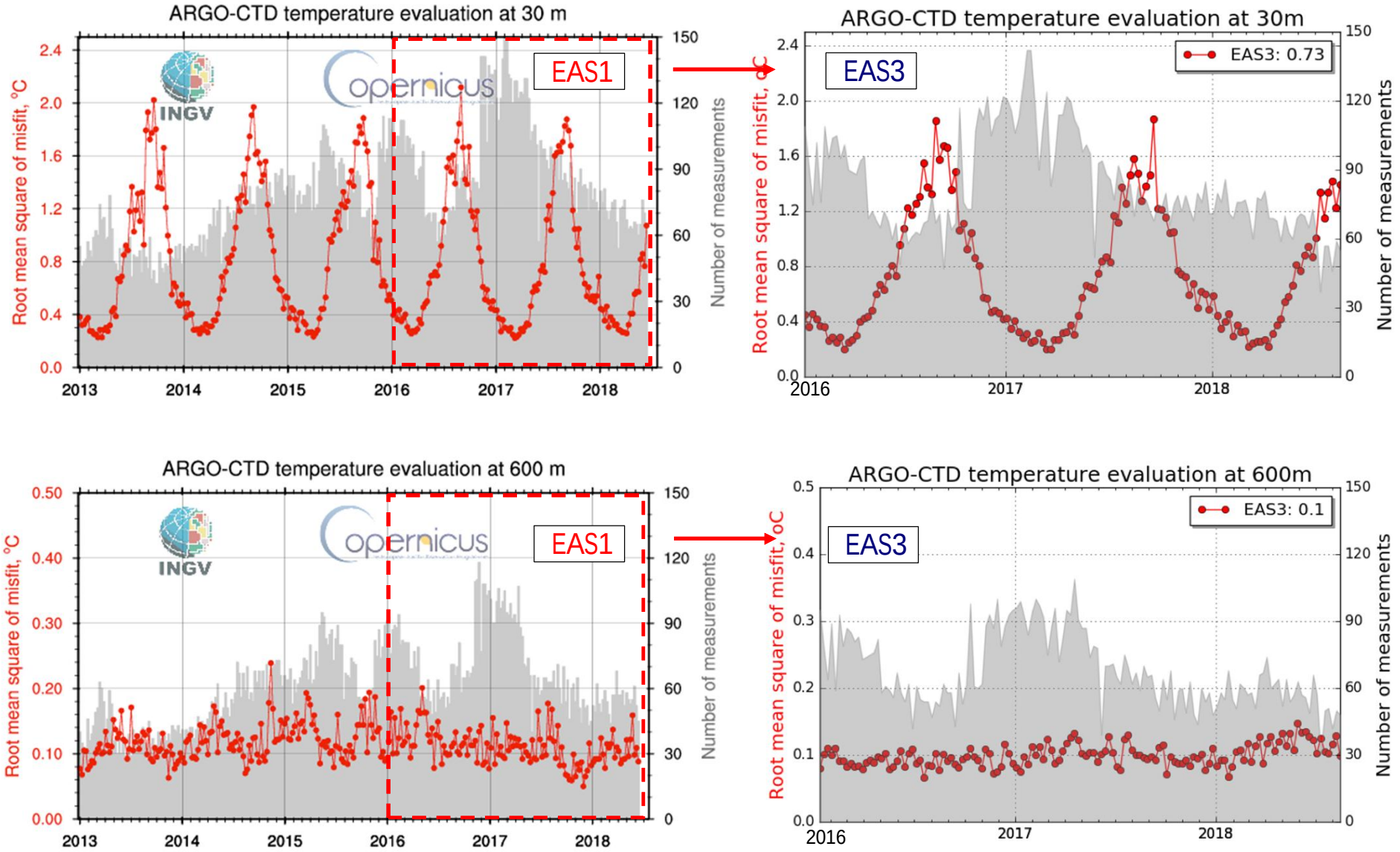
Time series of daily volume averaged salinity

comparison with WOA V2 climatological dataset



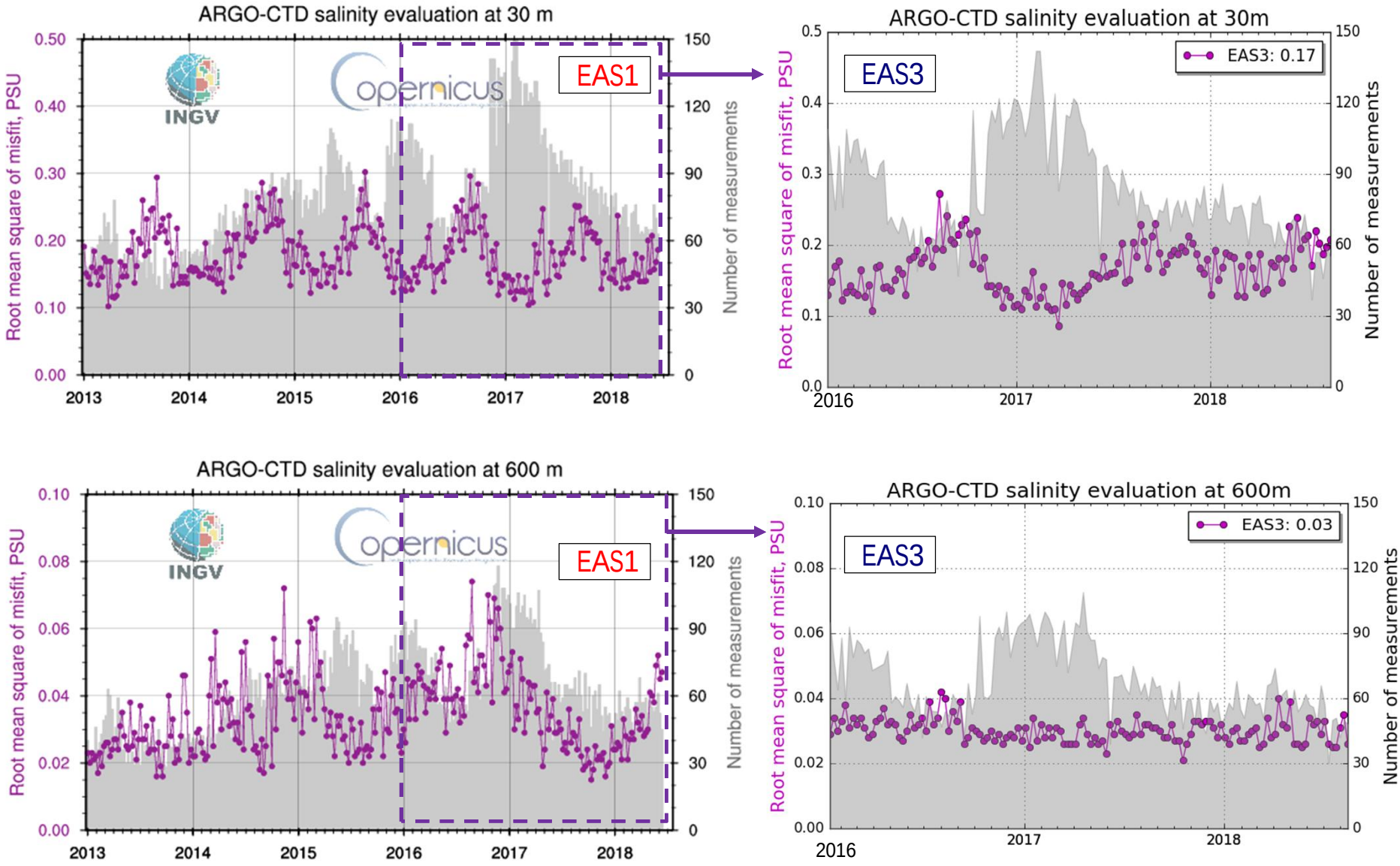
QUASI-INDEPENDENT VALIDATION: MISFITS

Time Series of Temperature RMS misfits ad depth



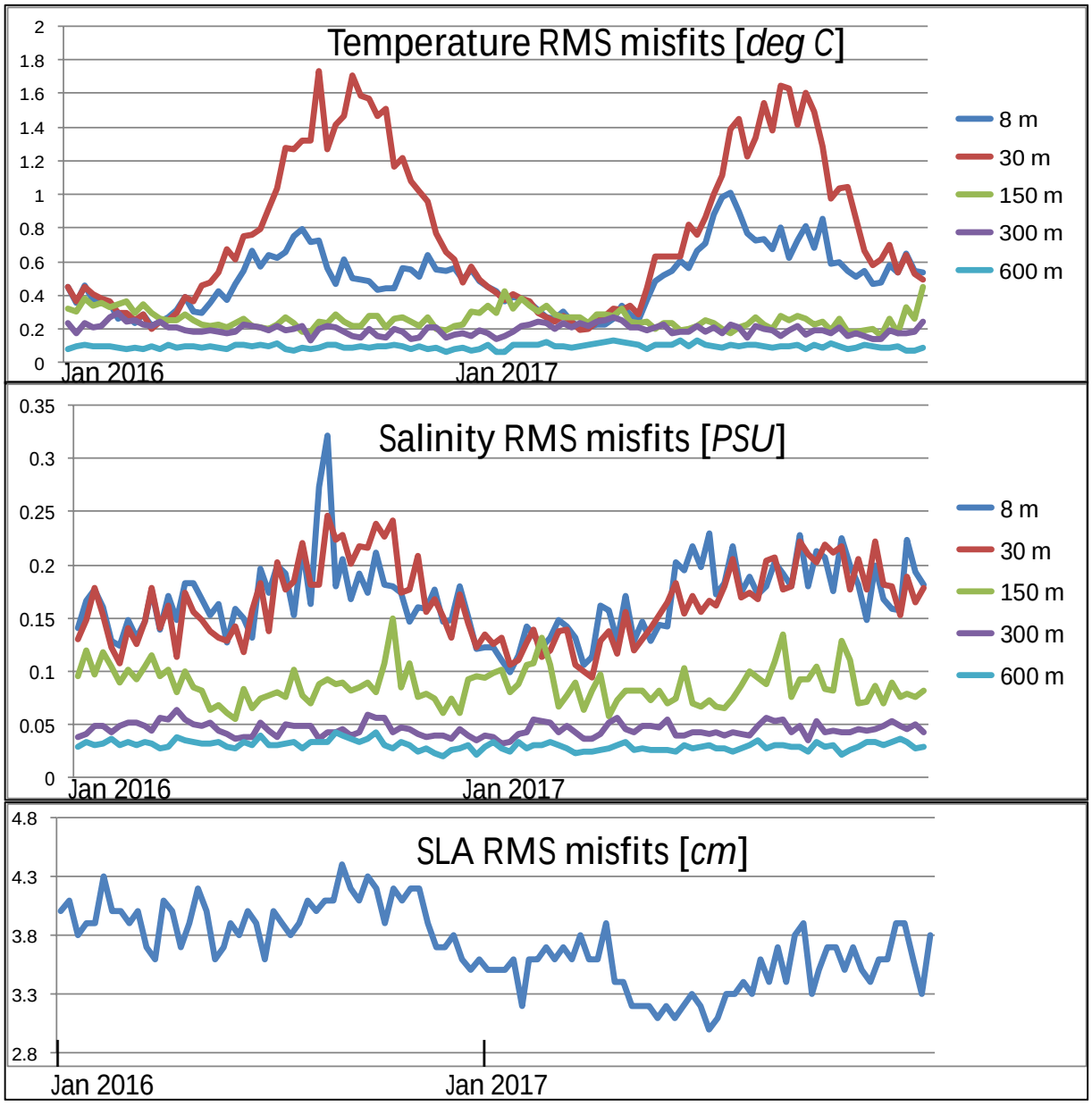
QUASI-INDEPENDENT VALIDATION: MISFITS

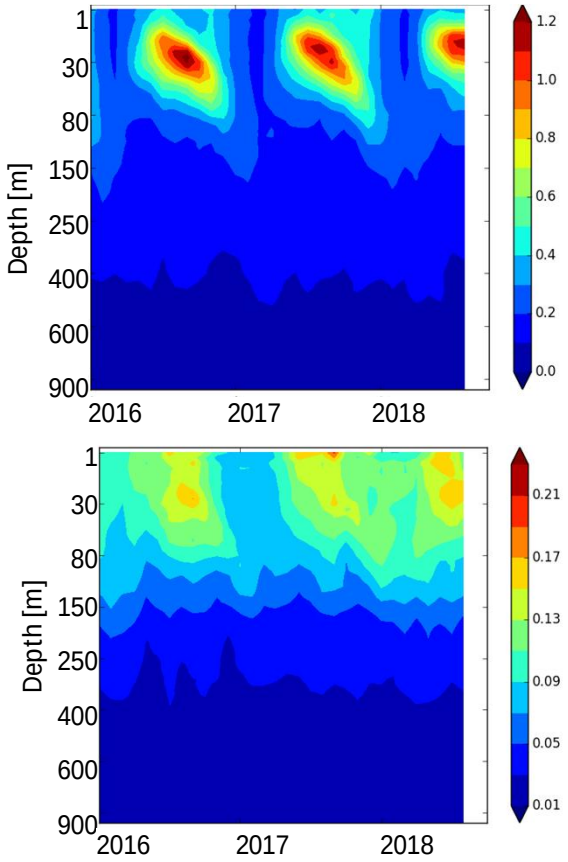
Time Series of Salinity RMS misfits ad depth



QUASI-INDEPENDENT VALIDATION: MISFITS

Temporal and vertical variability of T & S RMS misfits





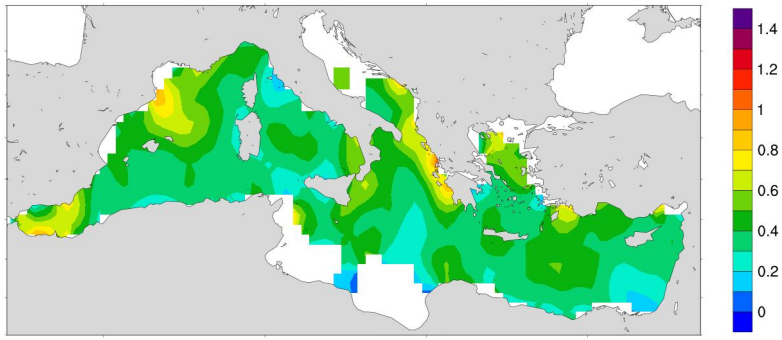
T/S

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

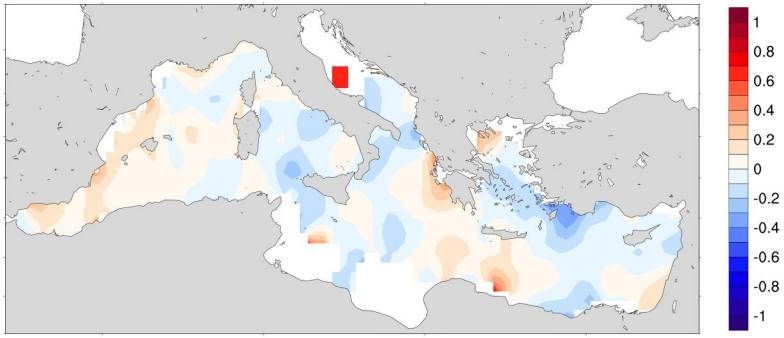
QUASI-INDEPENDENT VALIDATION: MISFITS

Spatial variability of T & S RMS misfits and Bias @ 8m: 2016-2018

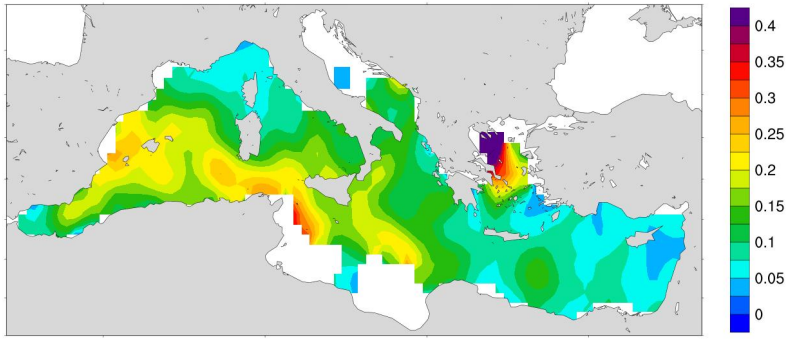
Temperature RMS mifits at 8m [*degC*]



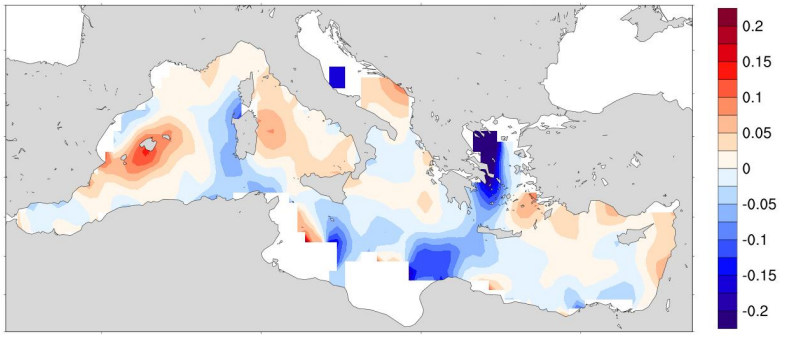
Temperature Bias at 8m [*degC*]



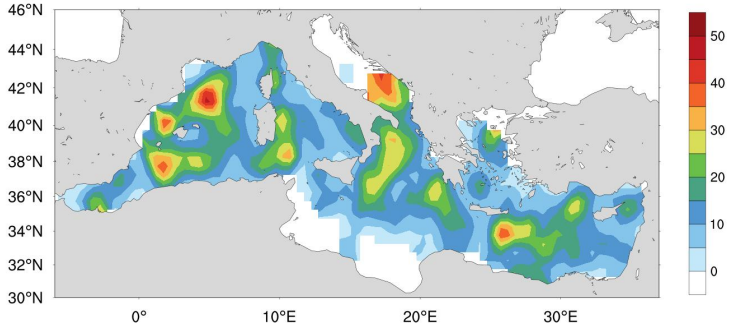
Salinity RMS mifits at 8m [*PSU*]



Salinity Bias at 8m [*PSU*]



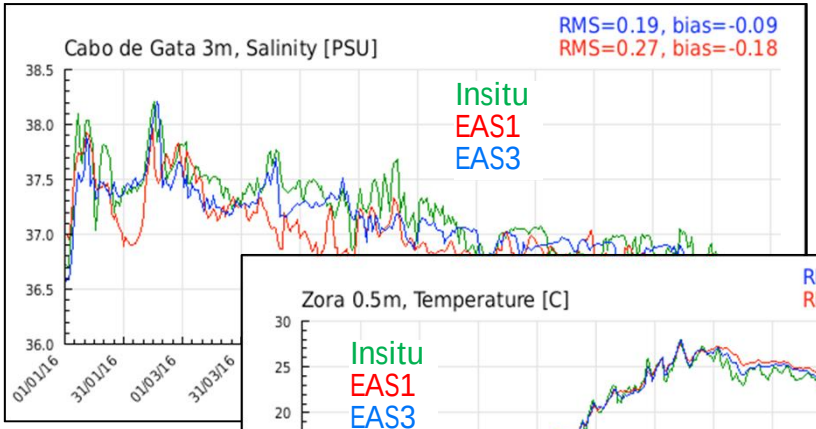
A N. Of Observations

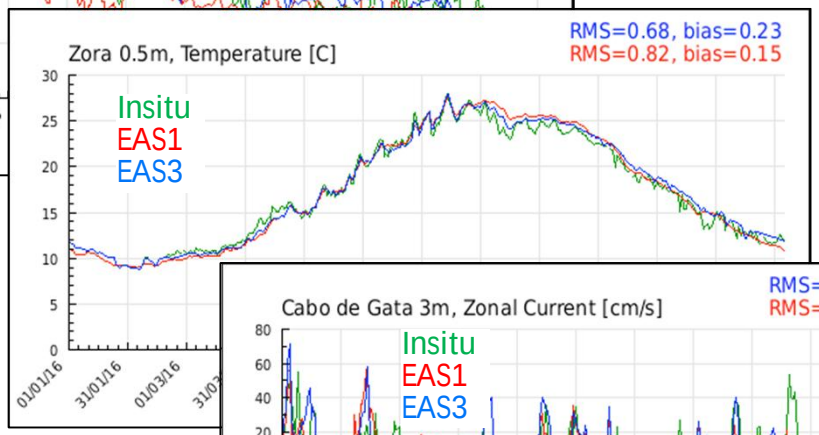


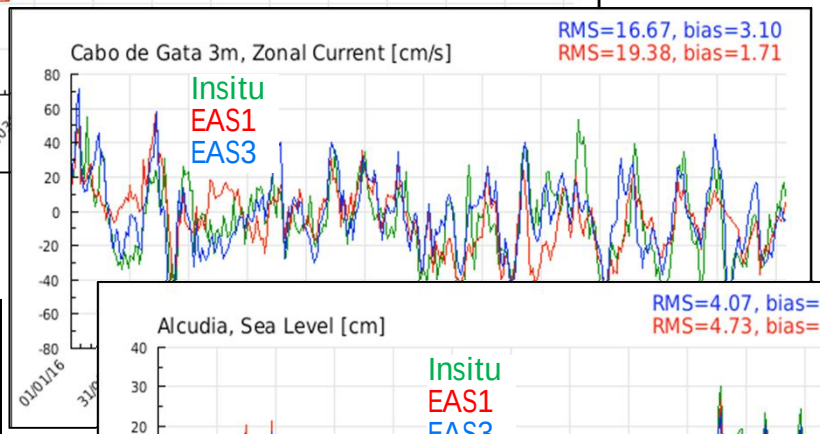
INDEPENDENT VALIDATION WITH COASTAL MOORINGS

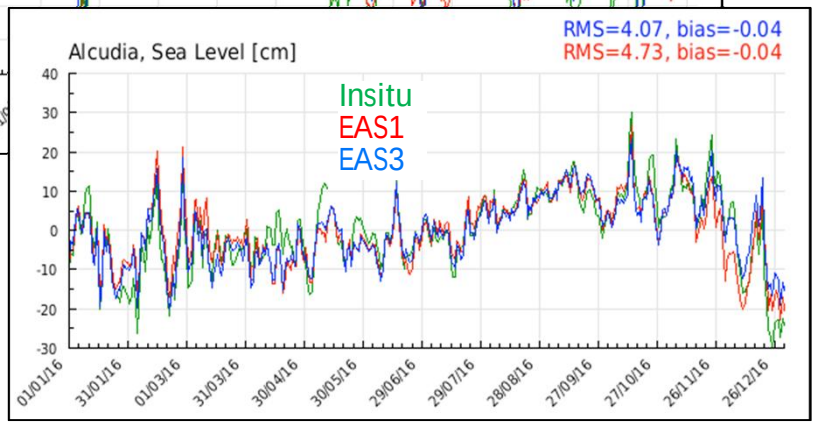
Independent validation

Daily mean Time series of model outputs vs. coastal moorings





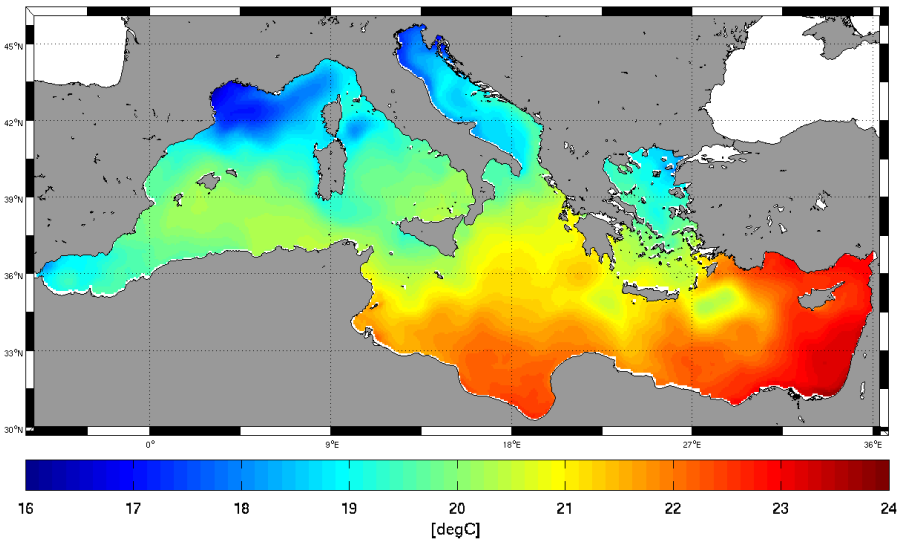




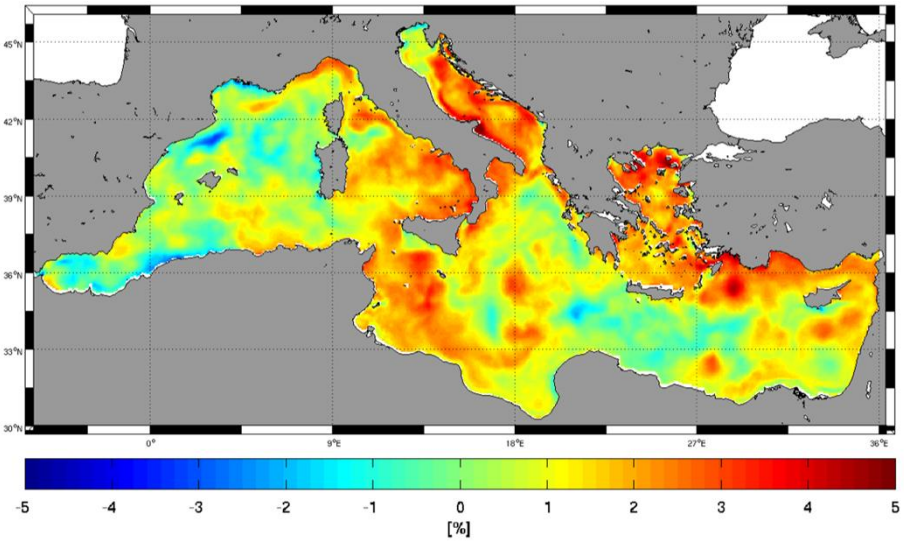
Variable	Year 2016		
	n. moorings	RMSD	Bias
Temperature [°C]	15	0.63	-0.05
Salinity [PSU]	8	0.41	0.22
Sea Level [cm]	49	4.62	-0.12
Zonal Vel. [cm/s]	8	11.59	0.67
Merid. Vel. [cm/s]	8	12.83	0.36

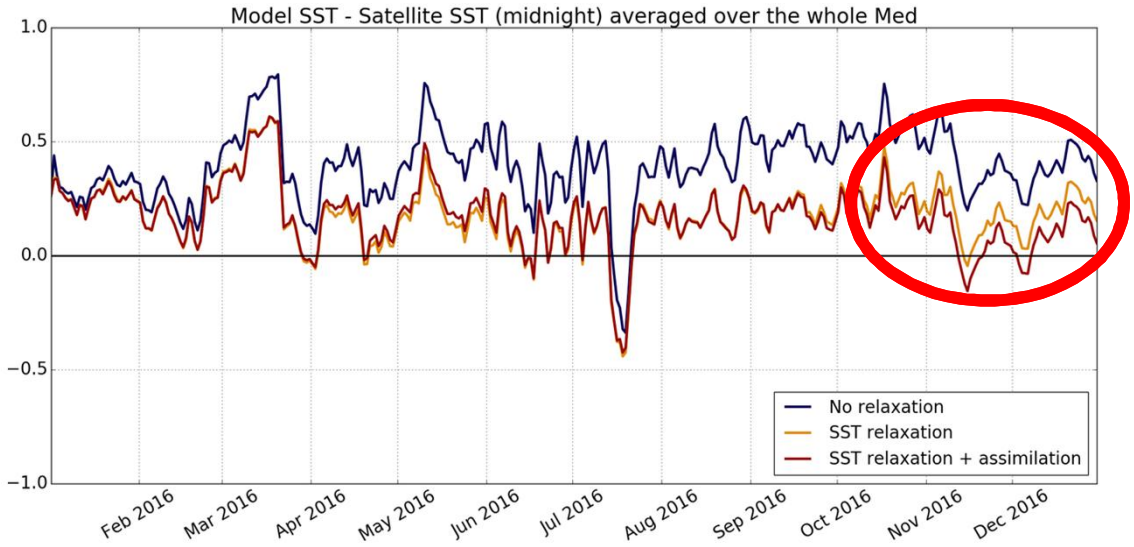
VALIDATION: 2D SST Maps comparison with satellite L4 dataset

Satellite SST Annual Mean (2016)



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





SST difference at midnight in the Mediterranean Sea

VALIDATION: Sea Bed Temperature

Bottom Temperature at depth: 0-1500m. : CLIM vs. model 2016

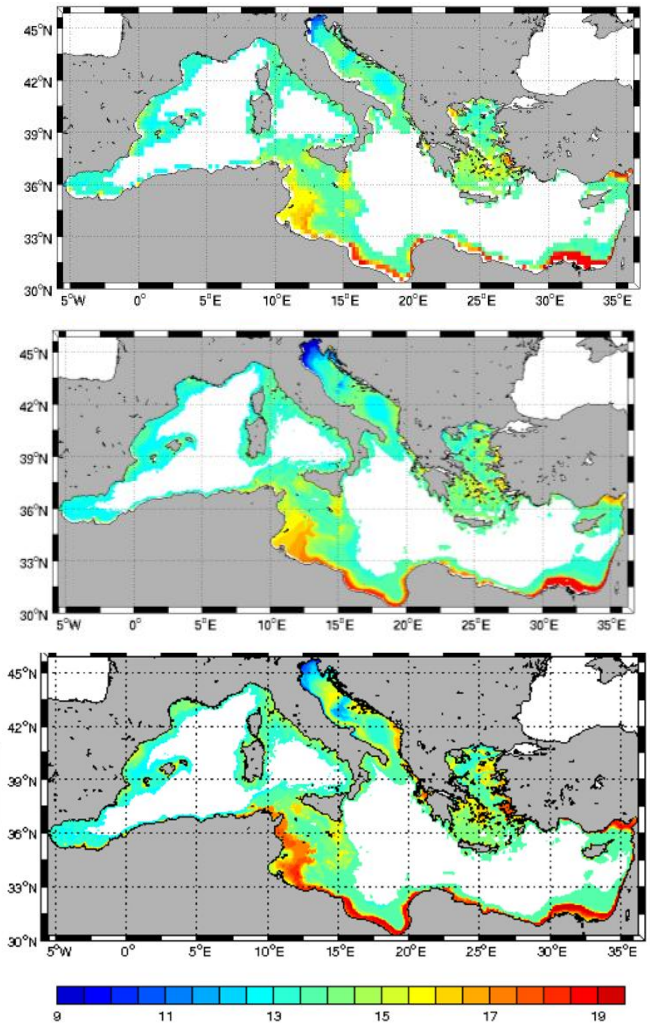
January

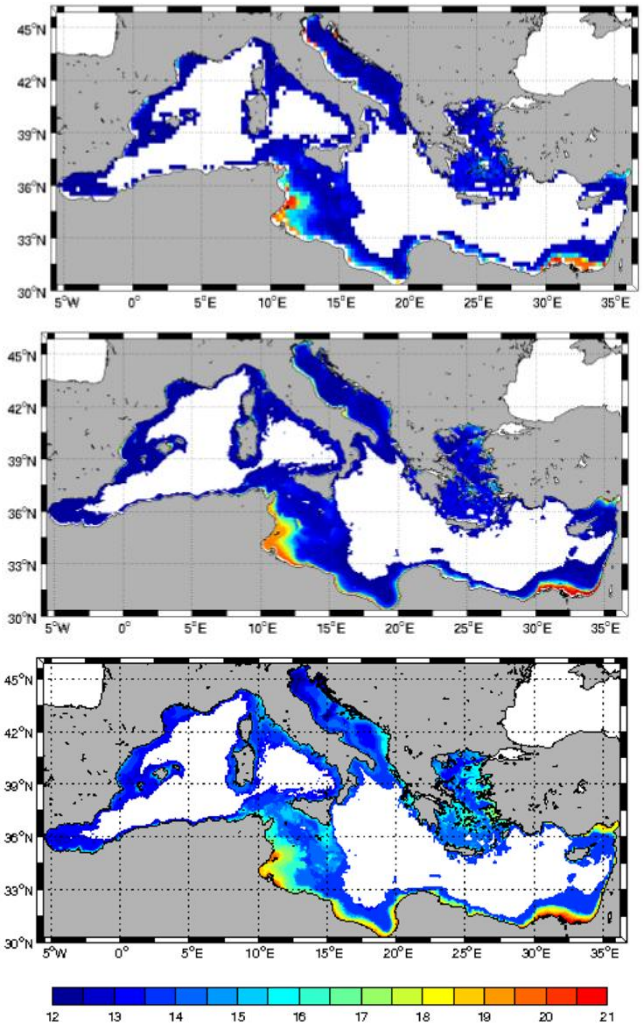
July

WOA CLIM

SDN CLIM

Model

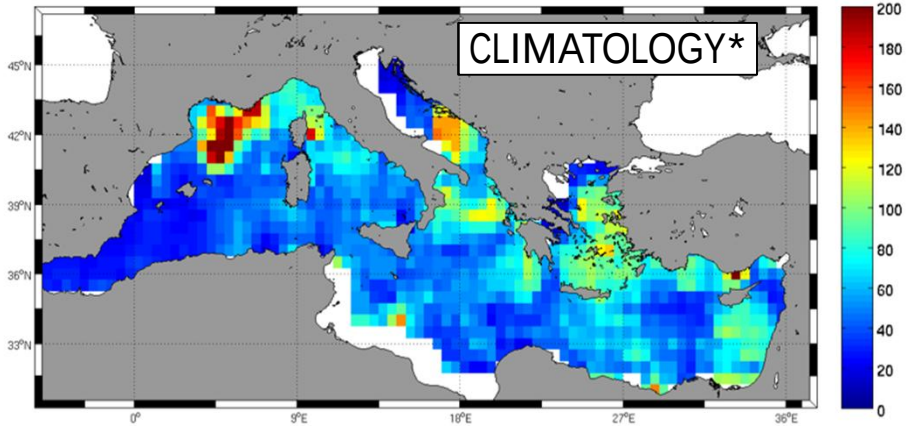


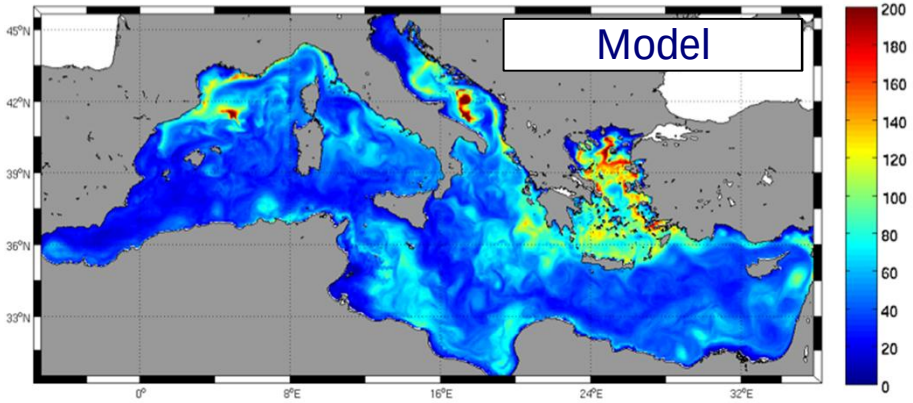


VALIDATION: Mixed Layer Depth

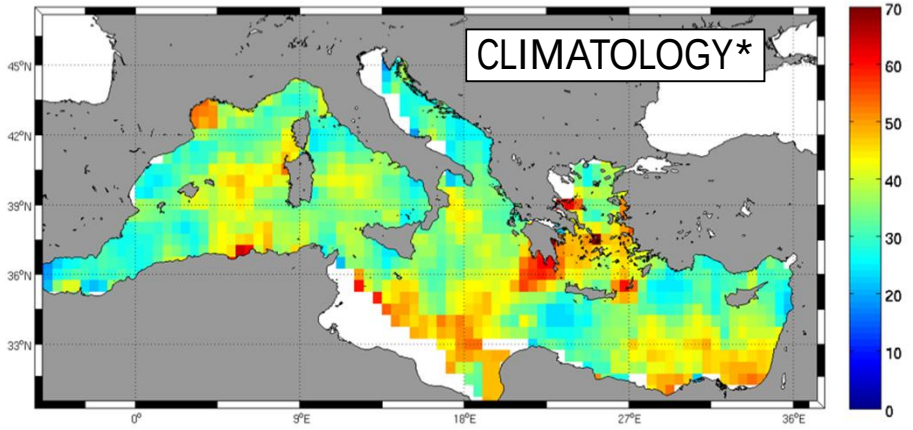
MLD : CLIM vs. model 2016

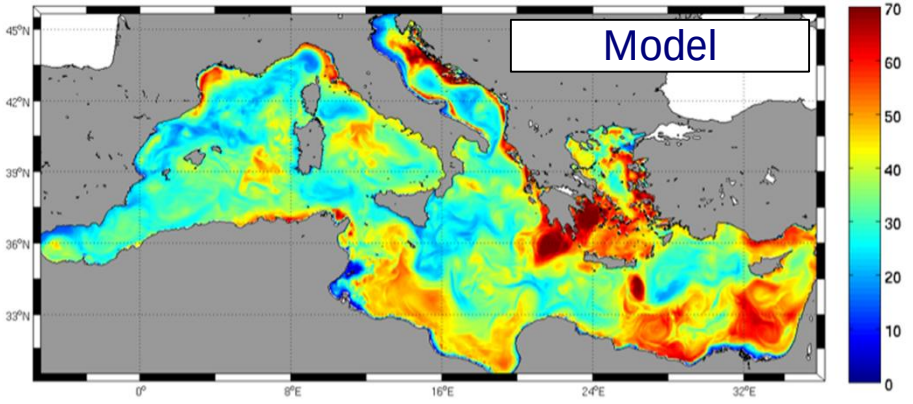
March





November

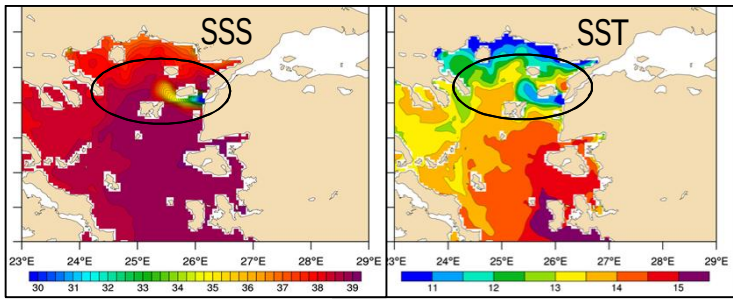




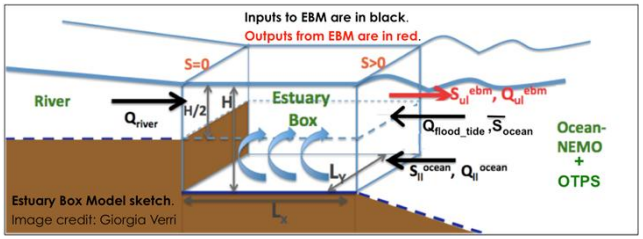
CLIMATOLOGY*: Houpert et al., 2015
Monthly gridded climatology produced using MBT, XBT, Profiling floats, Gliders, and ship-based CTD data from different database in the Med. 1969 - 2013

FUTURE WORKS

An upgraded analysis and forecasting system will enter in operation in April 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
- Implementation of a 1-way coupled Estuary Box Model at river mouth to better represent river inflow and salinity



Foreseen major upgrades in 2020:

- Include tides in the model
- Use a different vertical mixing scheme
- Use of high frequency inter-annual river run off, where available
- Include assimilation of SST
- Improvement of DA to account for Tides, new vertical mixing

Foreseen major upgrades in 2021:

- Improve on-line coupling of NEMO with wave model
- Use river forecast, where available, for major rivers

SUMMARY - CONCLUSIONS

- The actual Med Analysis and Forecast operational system has been presented highlighting major upgrades with previous version
  - Increased resolution (from 1/16 to 1/24 deg, from 72 to 141 vert lev)
  - Increased river inputs (from 7 to 39) aligned with Med-Biogeochemistry
  - Update of the OGCM model (from NEMO v3.4 to NEMO v3.6 with non-linear free surface and z* vertical coordinates)
  - Update of Data Assimilation scheme
- 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