INNOVATION IN THE FRAMEWORK OF THE ATLANTIC DEEP OCEAN

Innovative numerical model validation

Interreg Atlantic Area
European Regional Development Fund
EUROPEAN UNION
This project has received funding from the European Union's Interreg Atlantic Area programme under the grant EAPA_165/2016

Objectives & State of Arts

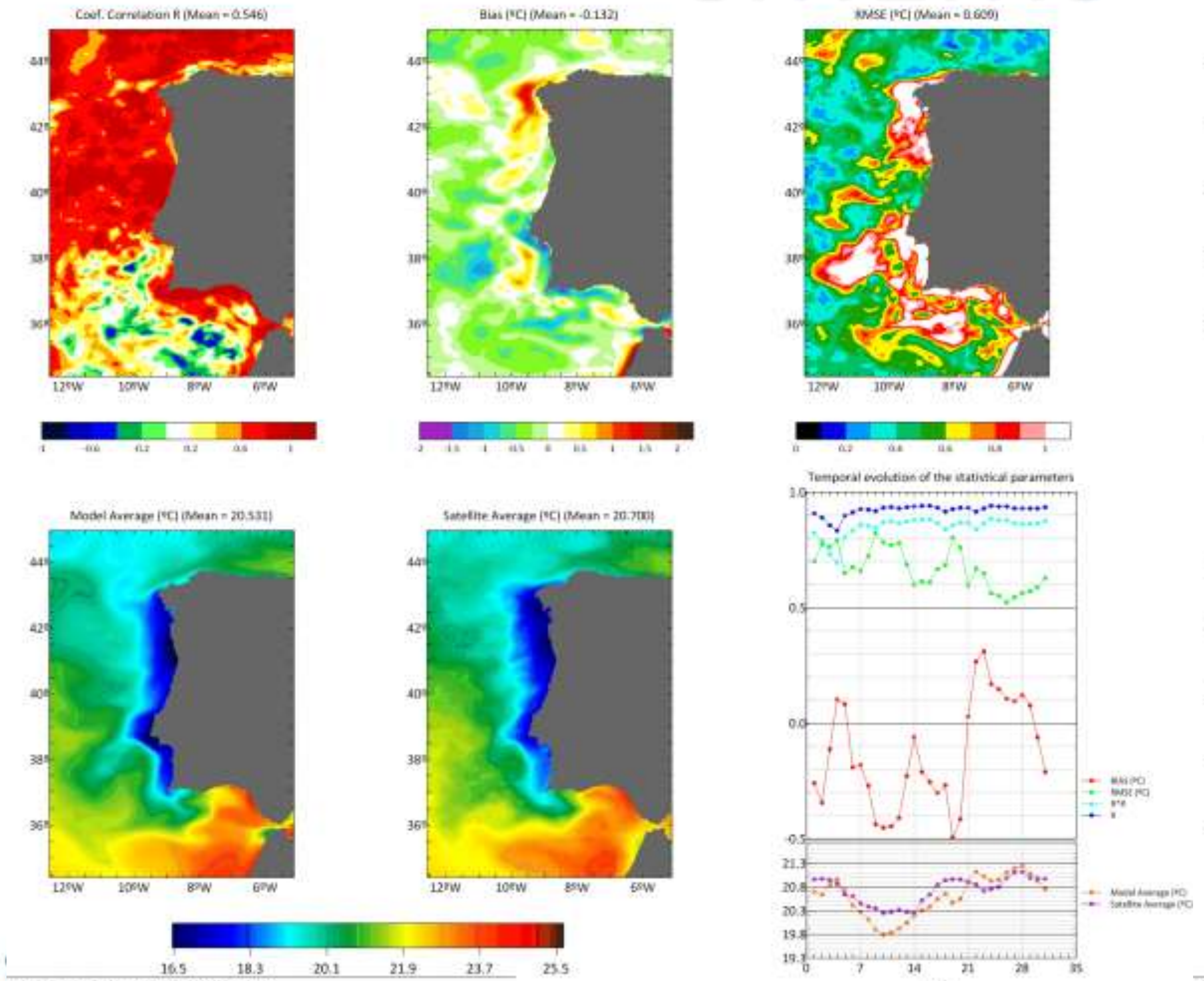
- Models needs validation, calibration and parameterization.
- Needs data.
- Difficulty of getting data in many regions of the ocean (open ocean, for example).
- iFADO provides several types of data
- Integration of different types of data to validate and calibrate the models (from iFADO partners and other sources)
- Satellite products, CTD, ARGO floats, BIO-ARGO floats, Gliders, climatology (WOA), other models, etc
- Integration of validation results and products from the models, like MSFD indices, helps in the implementation and parameterization
- **The modelling results have been validated with the in situ and remote sensing data made available during the iFADO project (e.g. D.7.3.3) .**
- **Development of tools to get data, validate models, compute MSFD indices (Action 4, D7.4.1, D7.4.2, D7.4.3)**

Remote Sensing

SST Validation - MUR

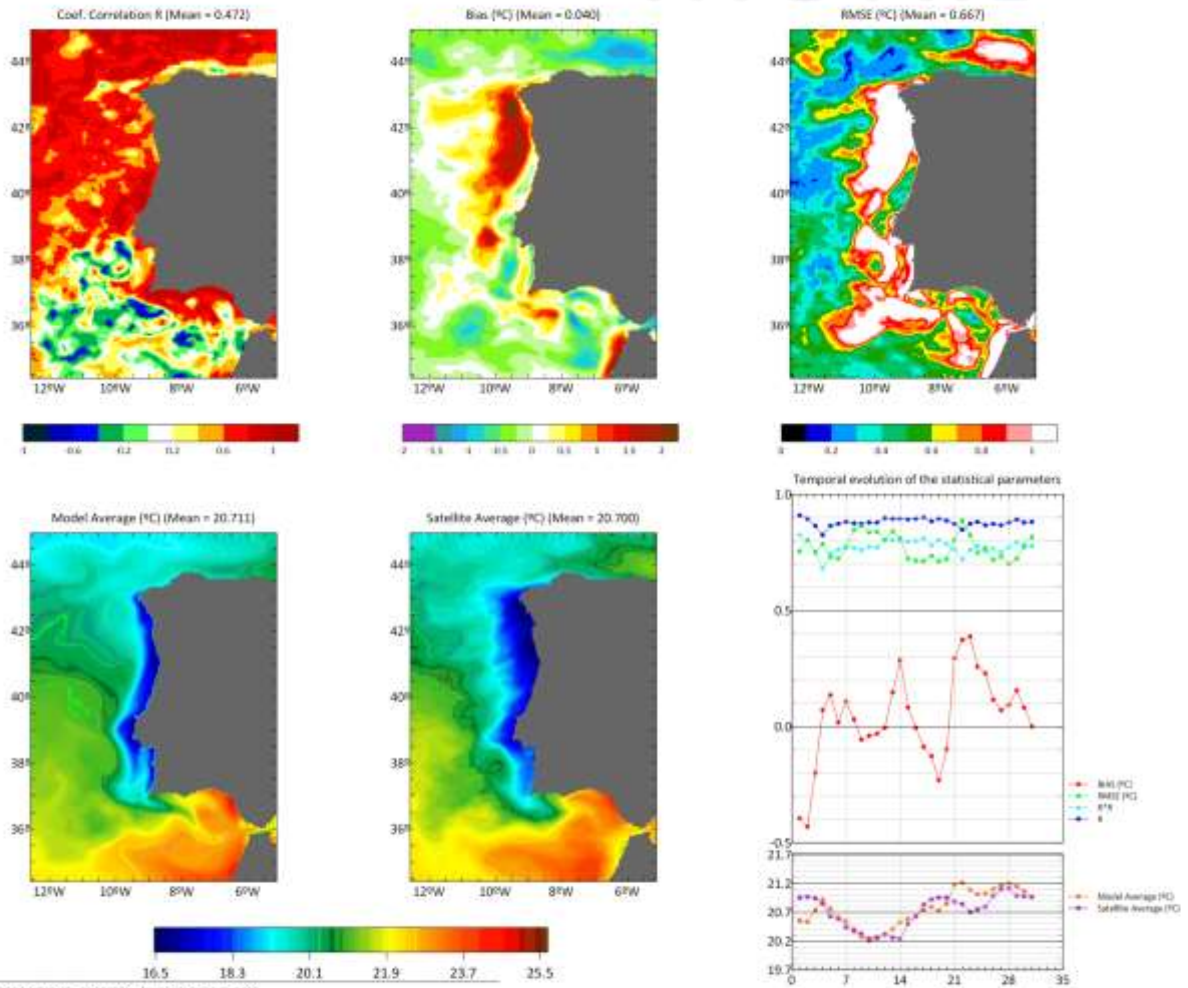
CMEMS SST vs Satellite SST (Microwave + Infra-red + In Situ)(*)

CMEMS

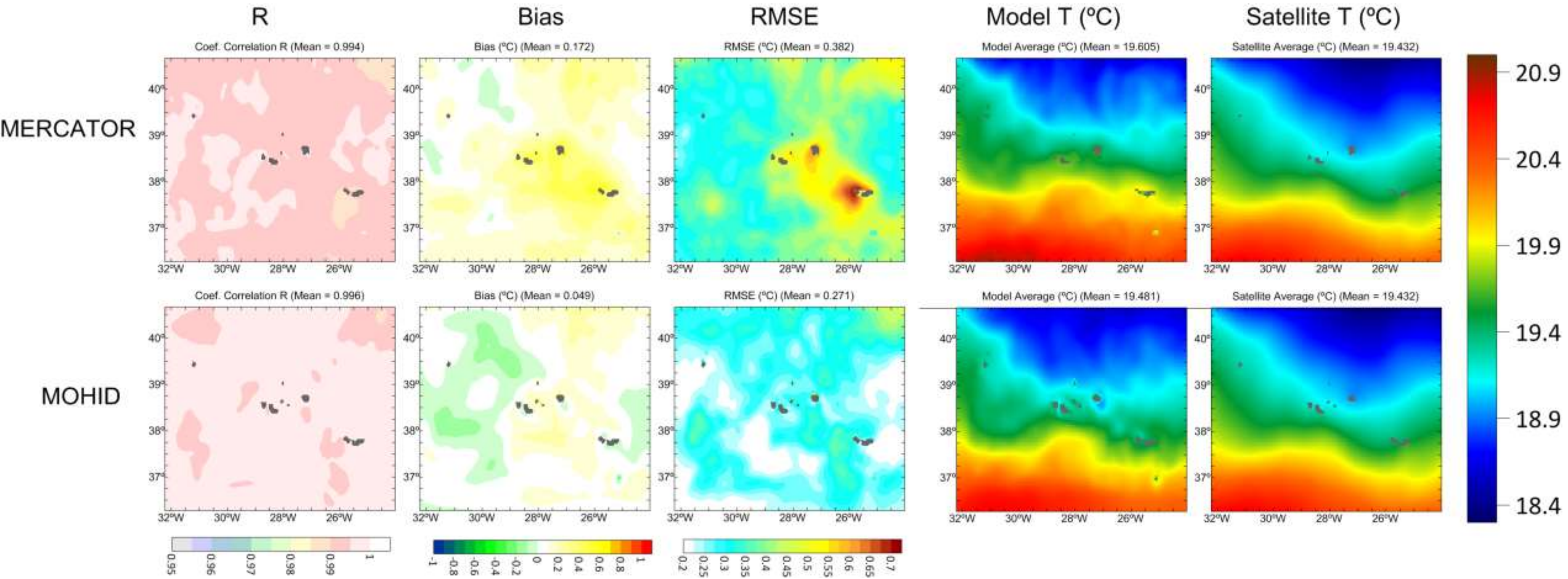


MOHID SST vs Satellite SST (Microwave + Infra-red + In Situ)(*)

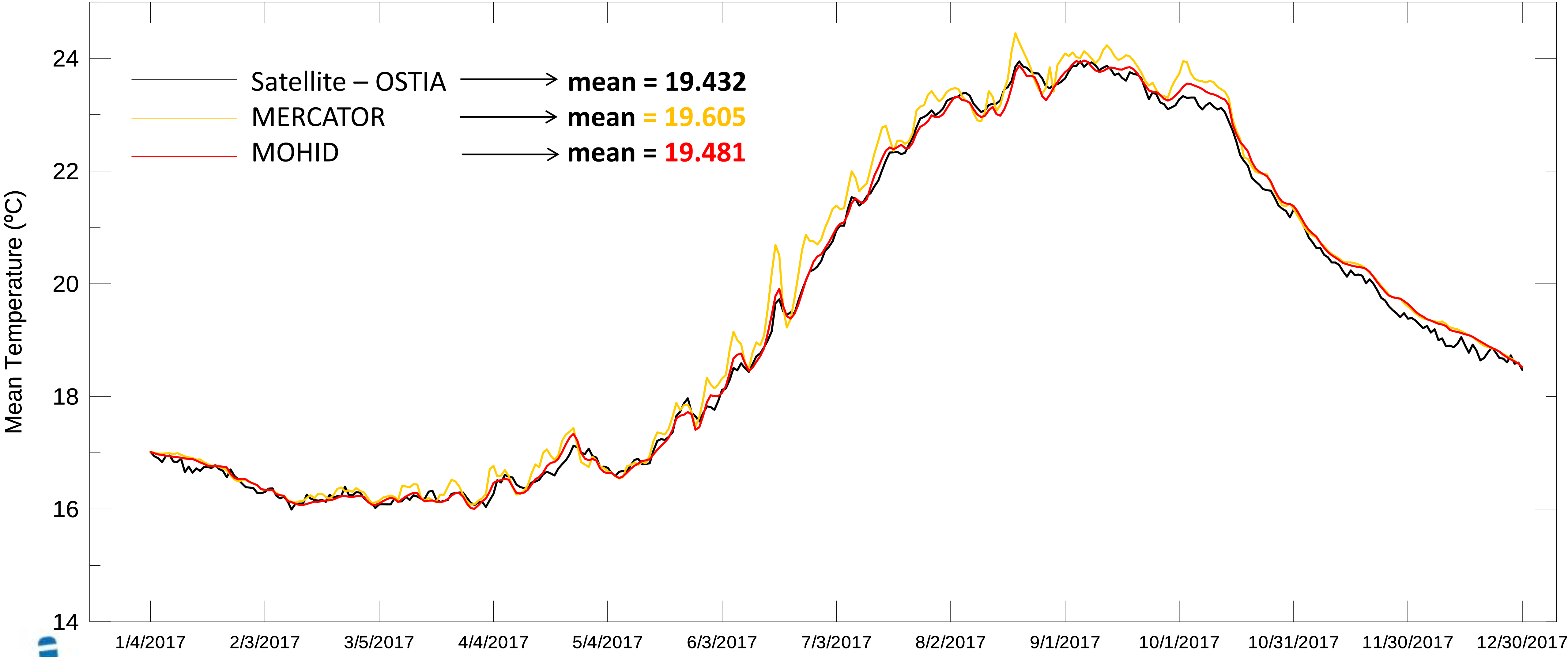
MOHID



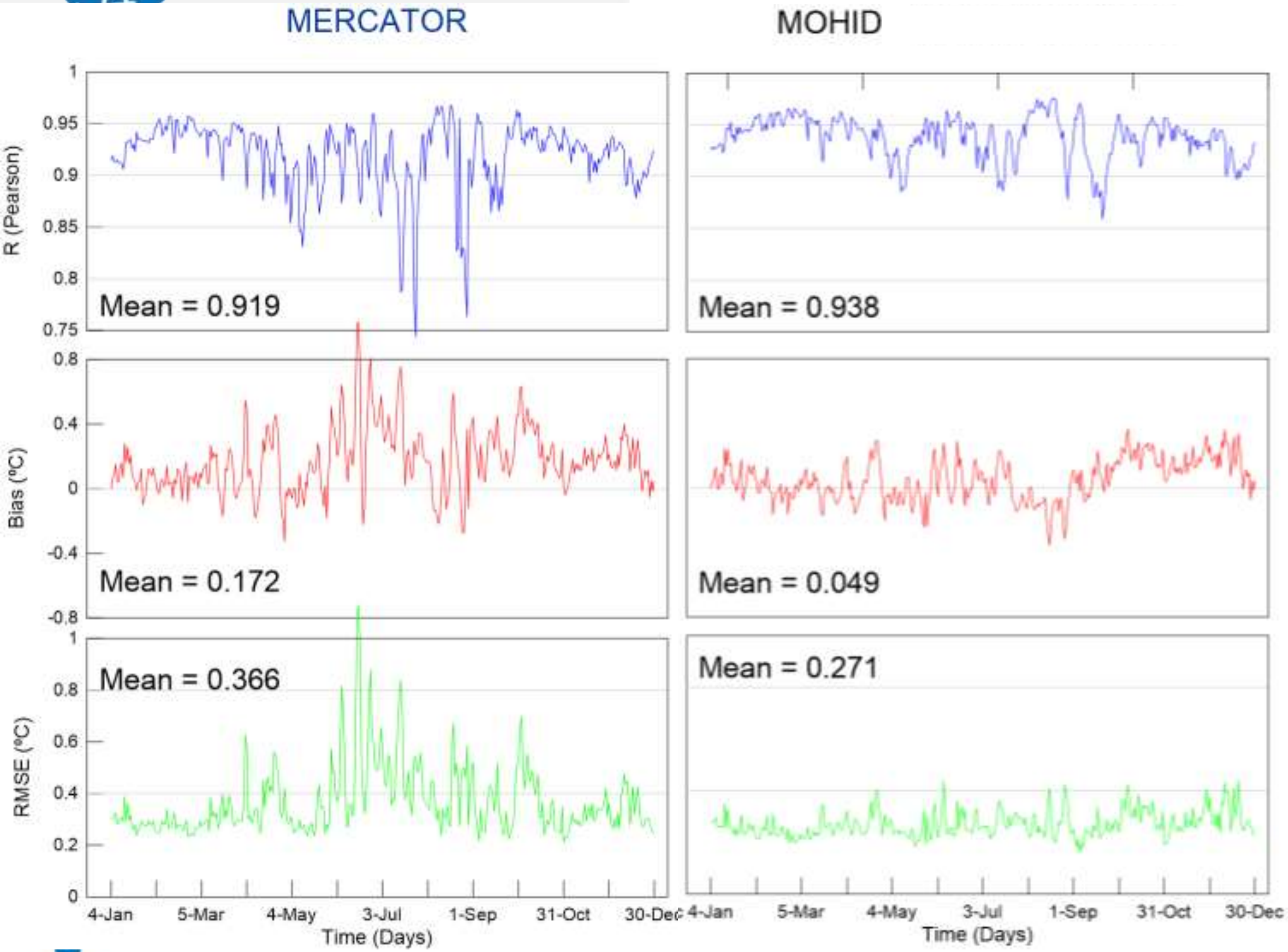
Comparison with OSTIA SST (2017 year)



Remote sensing validation (OSTIA ~5km resolution)



Remote sensing validation (OSTIA ~5km resolution)



Validation of SST (Azores model) against daily OSTIA satellite (2017 year)

Biogeochemical model – Validation and calibration

II.5.5 How to intercompare the chlorophyll-a observation with a bio model product?

Vertical profile of chlorophyll-*a* from modelling should be averaged over the optical depth with a weighting factor exponentially decreasing (g(z)). This factor is set to 1 for surface concentration and set to 0 for concentration at the bottom of the optical layer (Gordon and Clark, 1980 [RD39]). The integration formula is:

$$\boxed{C = \frac{\int_0^{Zeu} CHL(z) * g(z) * dz}{\int_0^{Zeu} g(z) * dz}}$$

With g(z), the weighting factor defined as:

$$\boxed{g(z) = e^{(-2*KD490*z)}}$$

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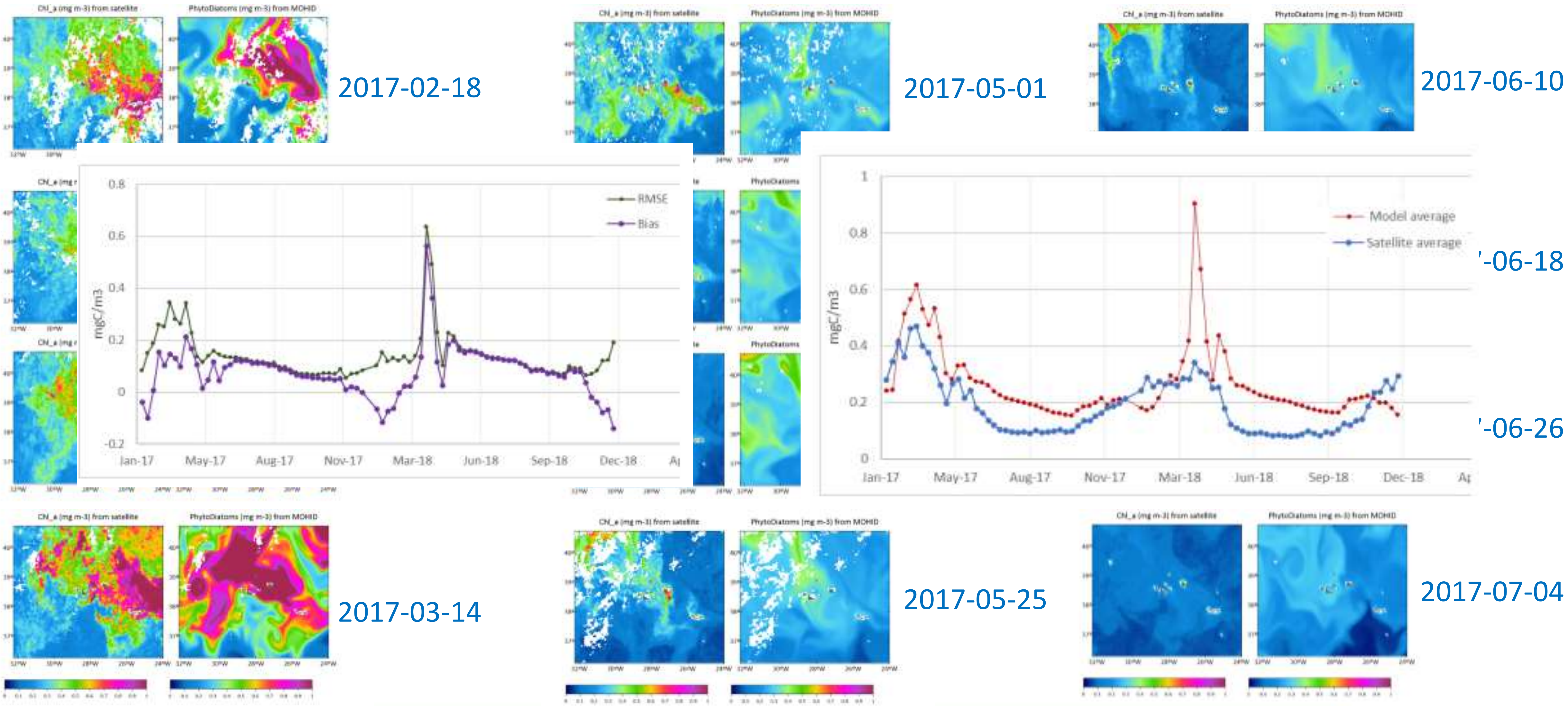
In CMEMS-OC-QUID-009-030-032-033-037-081-082-083-085-086-098.pdf, Copernicus Quality Information Document

Biogeochemical model in the Azores – Validation and calibration

CHL_A (OceanColor-CCI-Merged v5.0, L3)(Global, 4Km resol, 8 day)



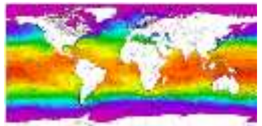
Model validation at the surface

- Nutrients (Nitrate, Phosphate, Silicate)
- Dissolved oxygen

MOHID
Water Modelling System

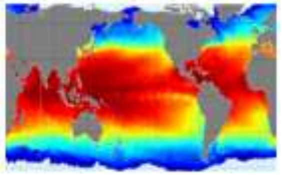
VS

World Ocean Atlas 2018 (WOA18)- Climatology based on in-situ data

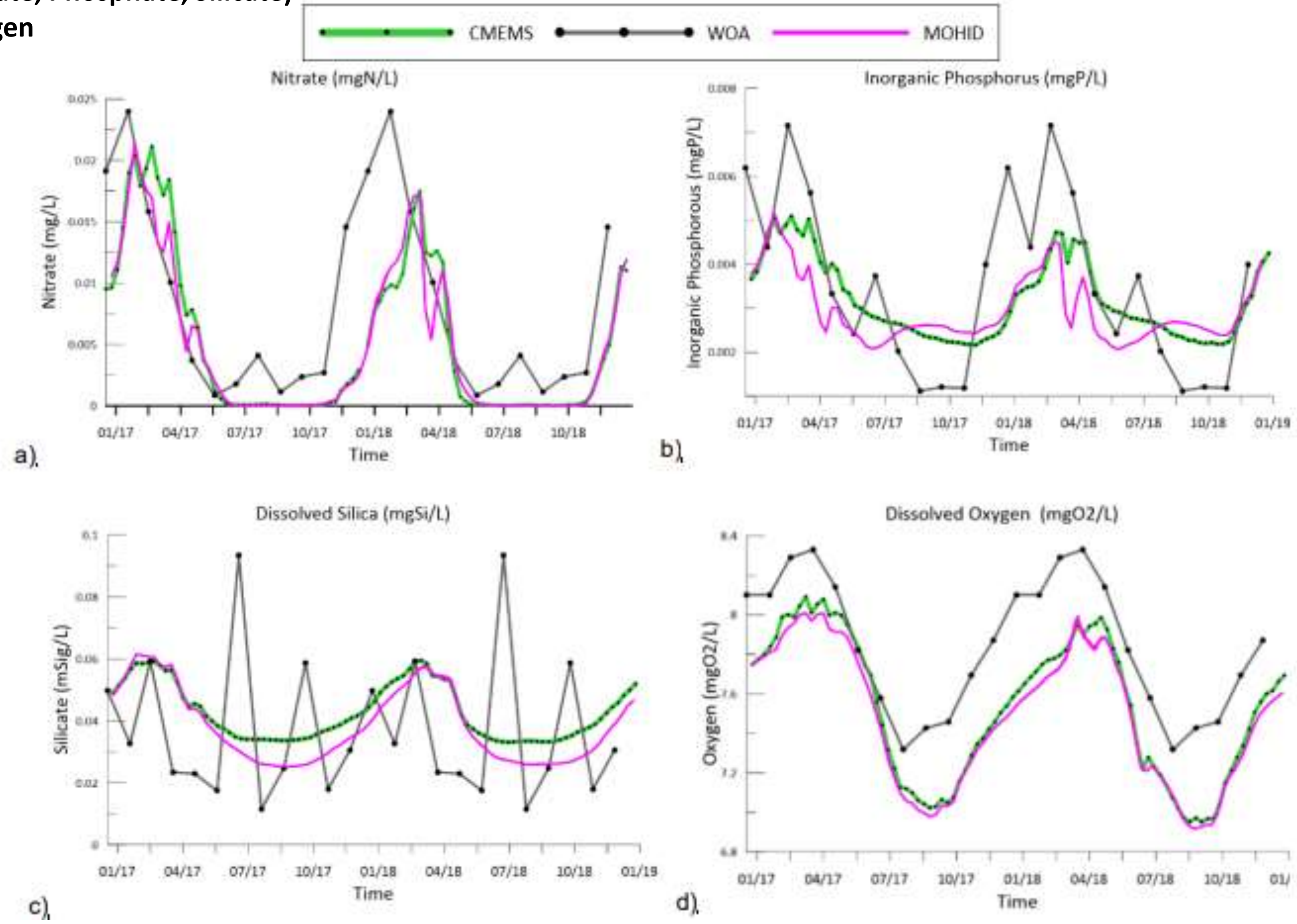


Garcia et al., 2018
https://www.ncei.noaa.gov/archive/accession/NCEI-WOA18

Copernicus model- Global Ocean Physics Analysis 0.08º



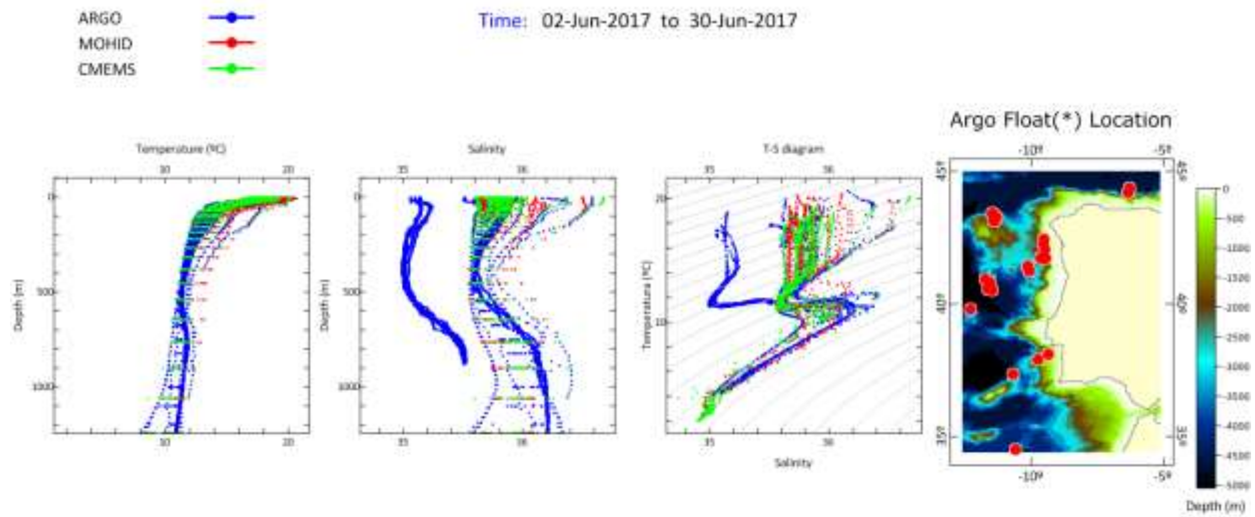
https://data.marine.copernicus.eu/products

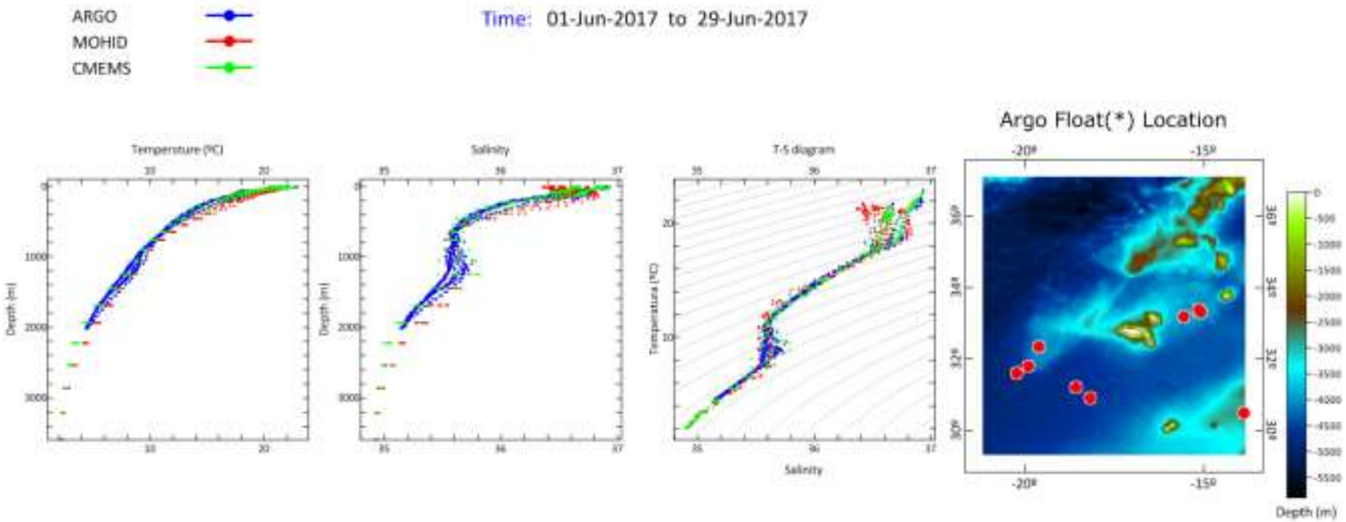


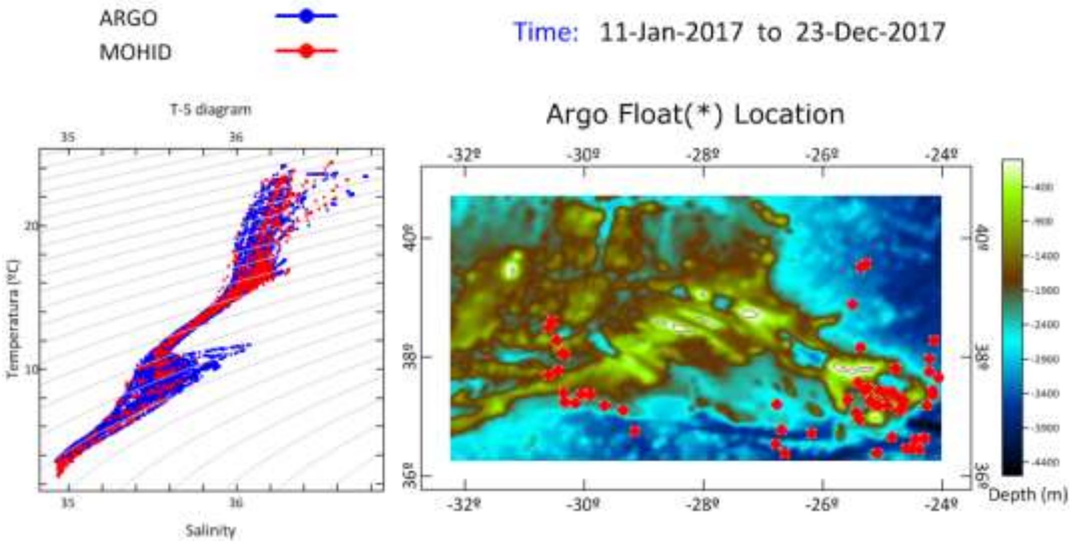
Credits: Cláudia Viegas

ARGO floats

Validation Results – ARGO Floats



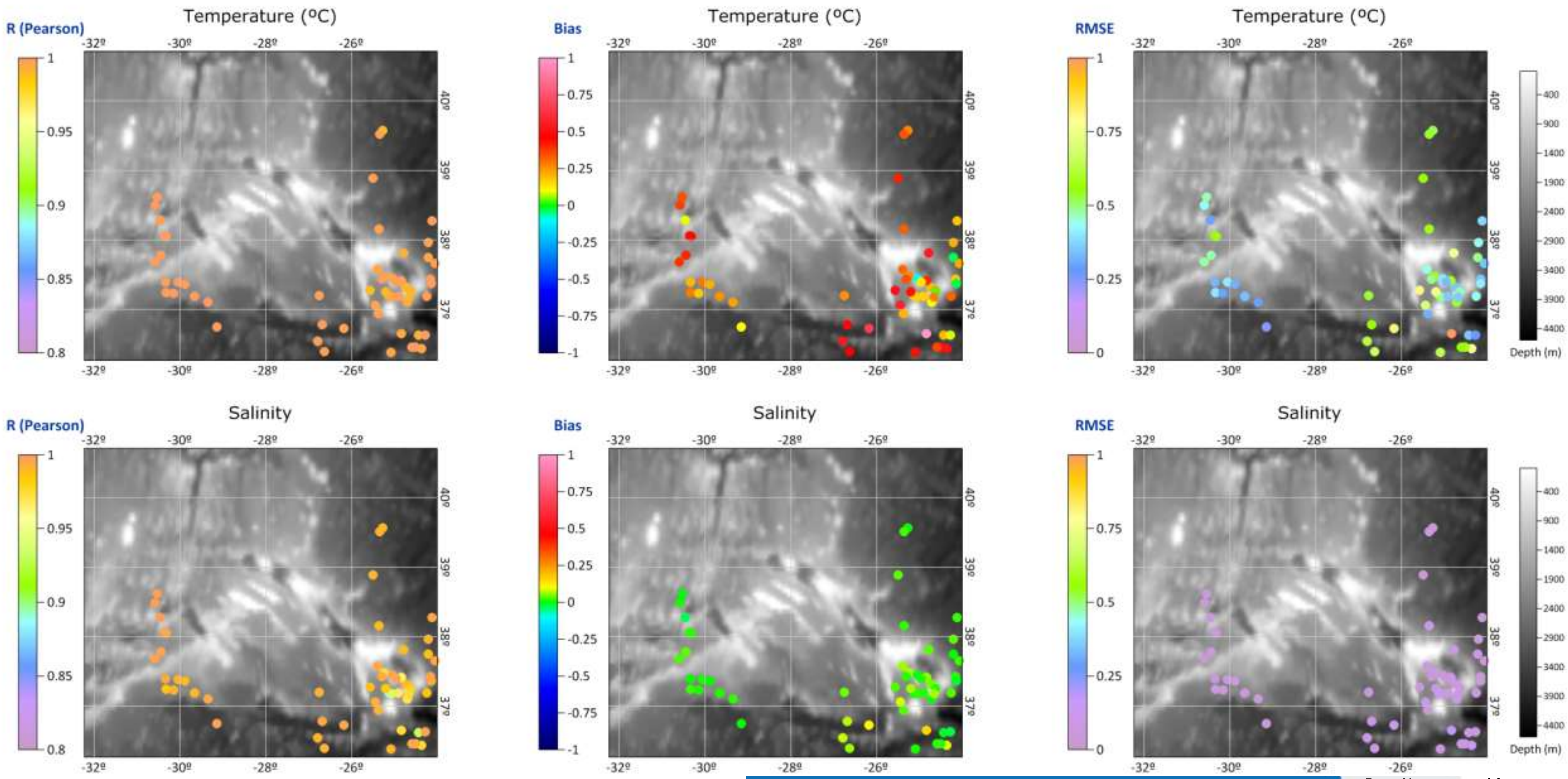




MOHID vs Argo floats

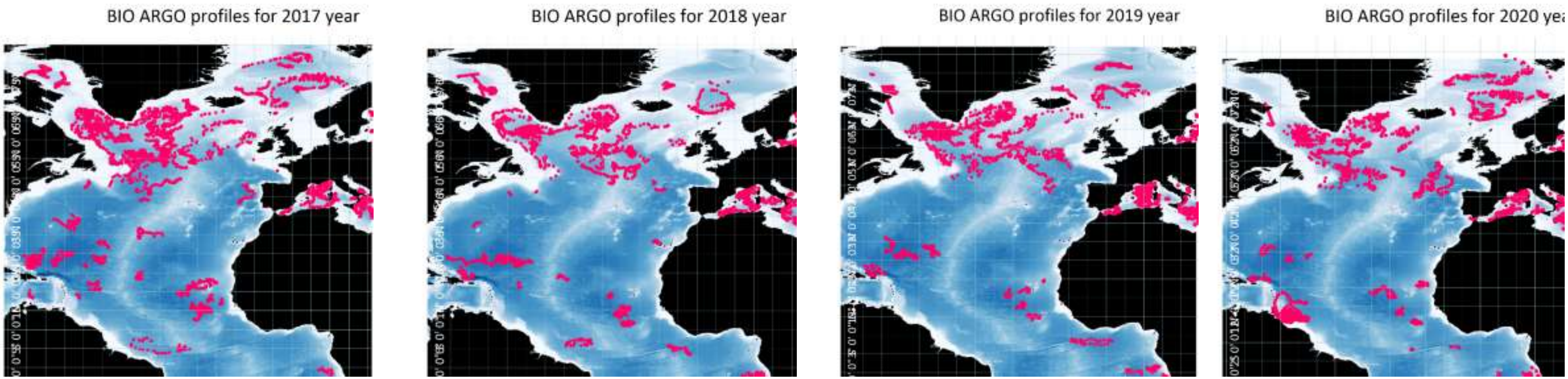
Total floats for Temperature: 58
Total floats for Salinity: 58

11-Jan-2017 to 23-Dec-2017

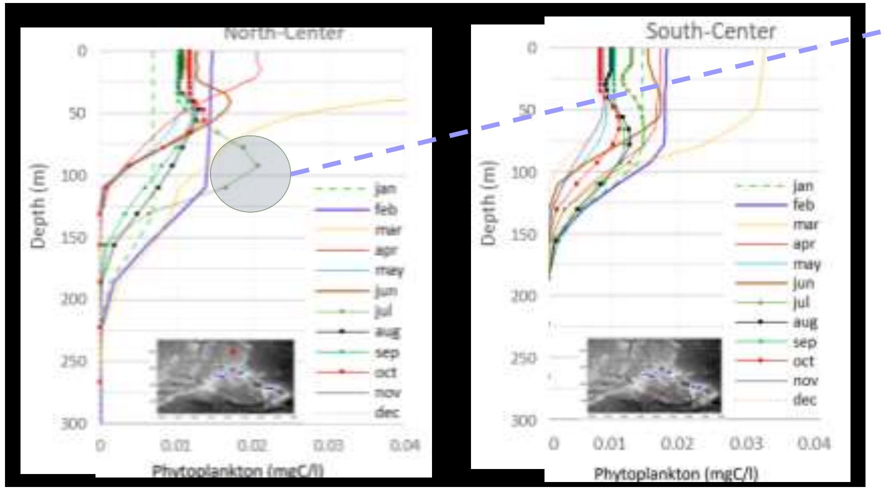


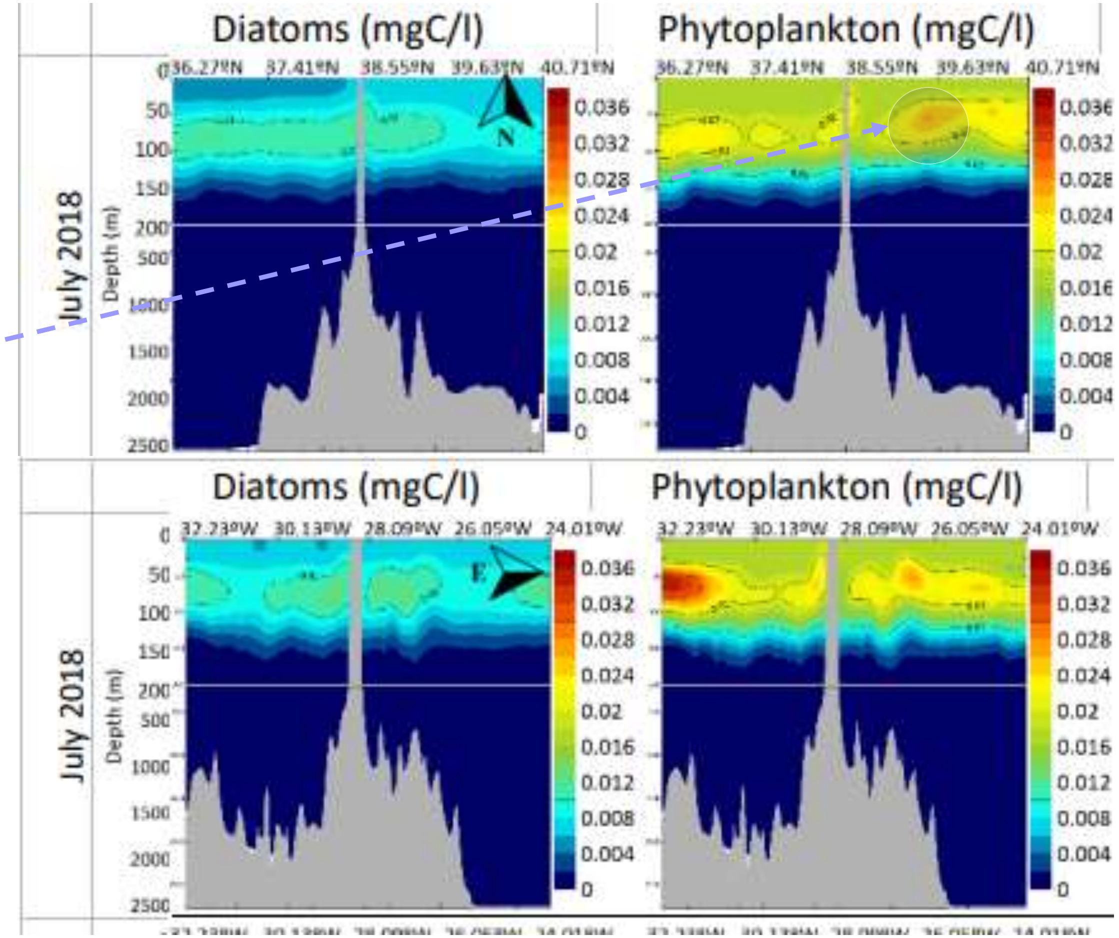
BIO-ARGO floats

BIO-ARGO Distribution



Biogeochemical model- Deep chlorophyll maximum (DCM)



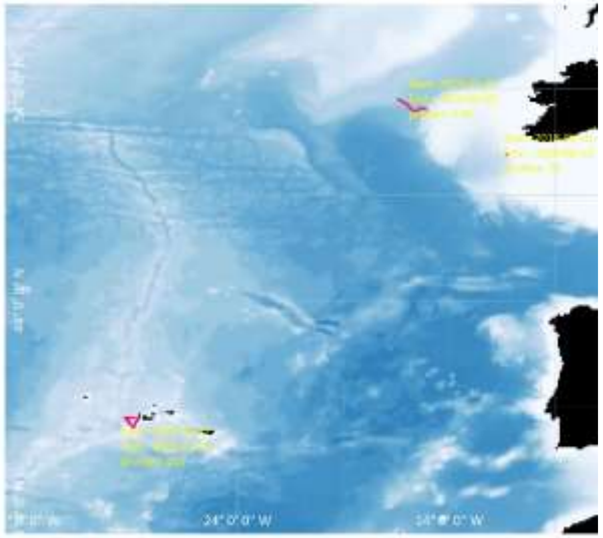


- Spatial and seasonal variability in the Azores region are well represented
  - Along the water column
    - **Deep chlorophyll maximum**- is well established
    - DCM- between between 50 and 100 meters depth
    - Higher phytoplankton concentrations in the North of the domain
    - North

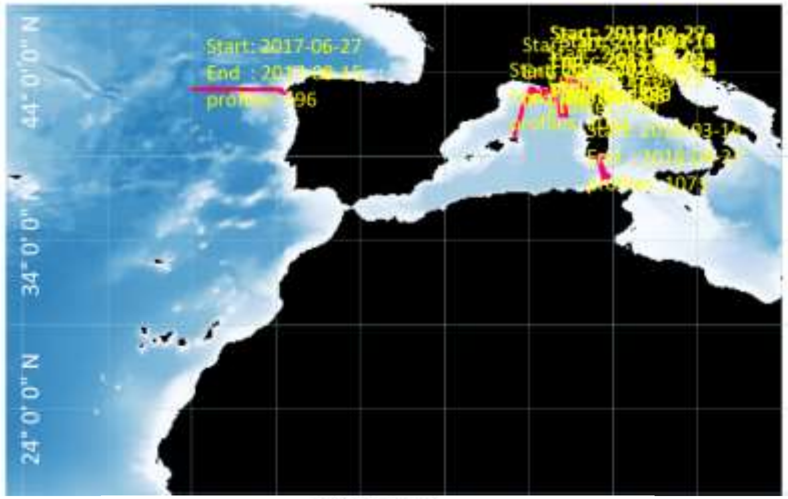
Gliders

Glider Distribution

Glider: laochra-na-mara

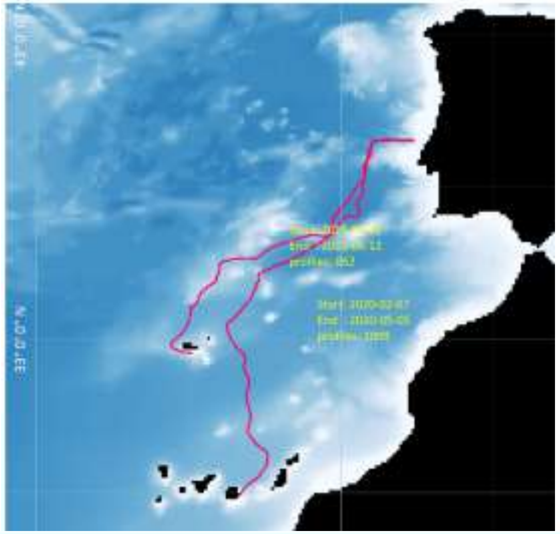


Glider: bonpland



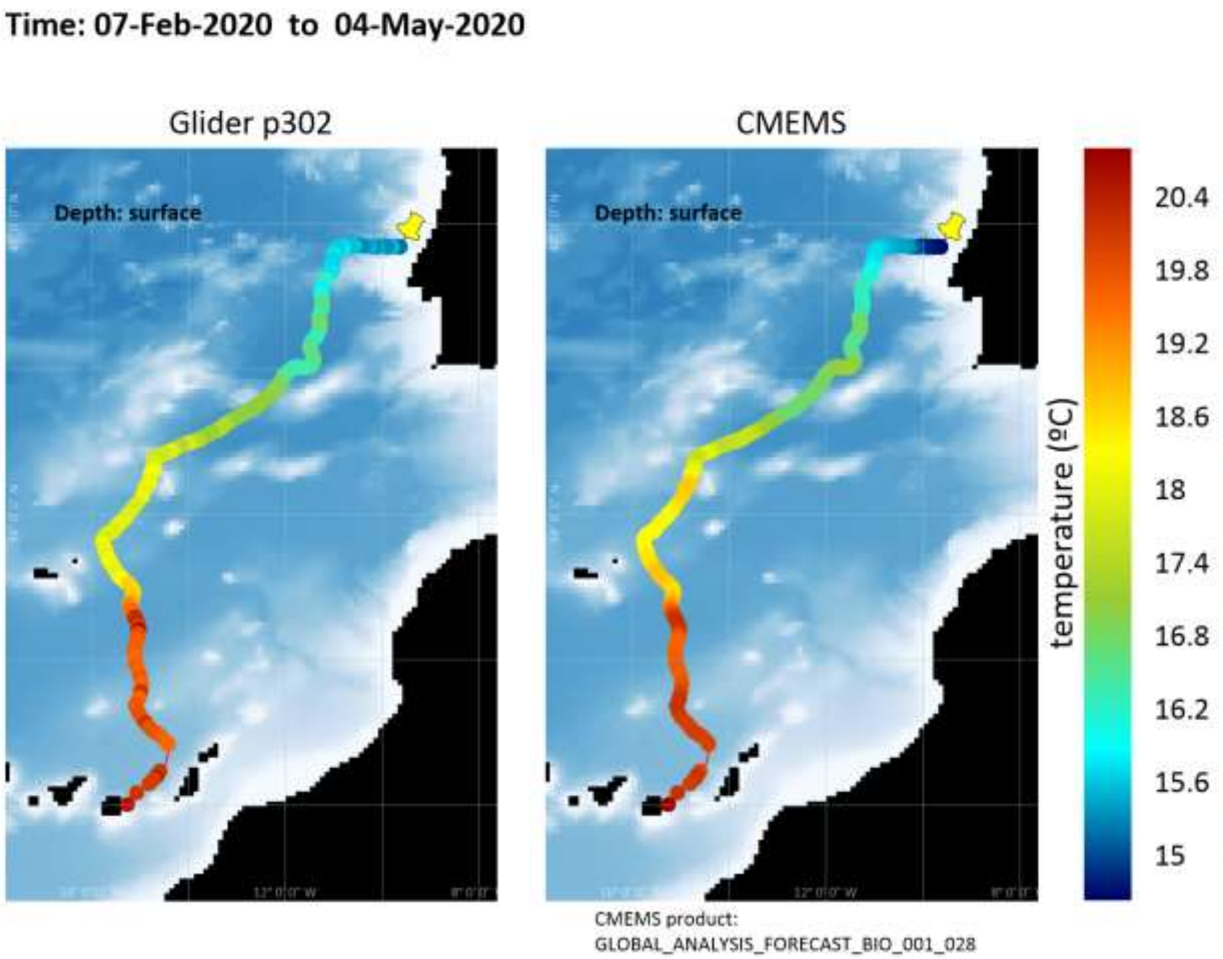
Glider: p201

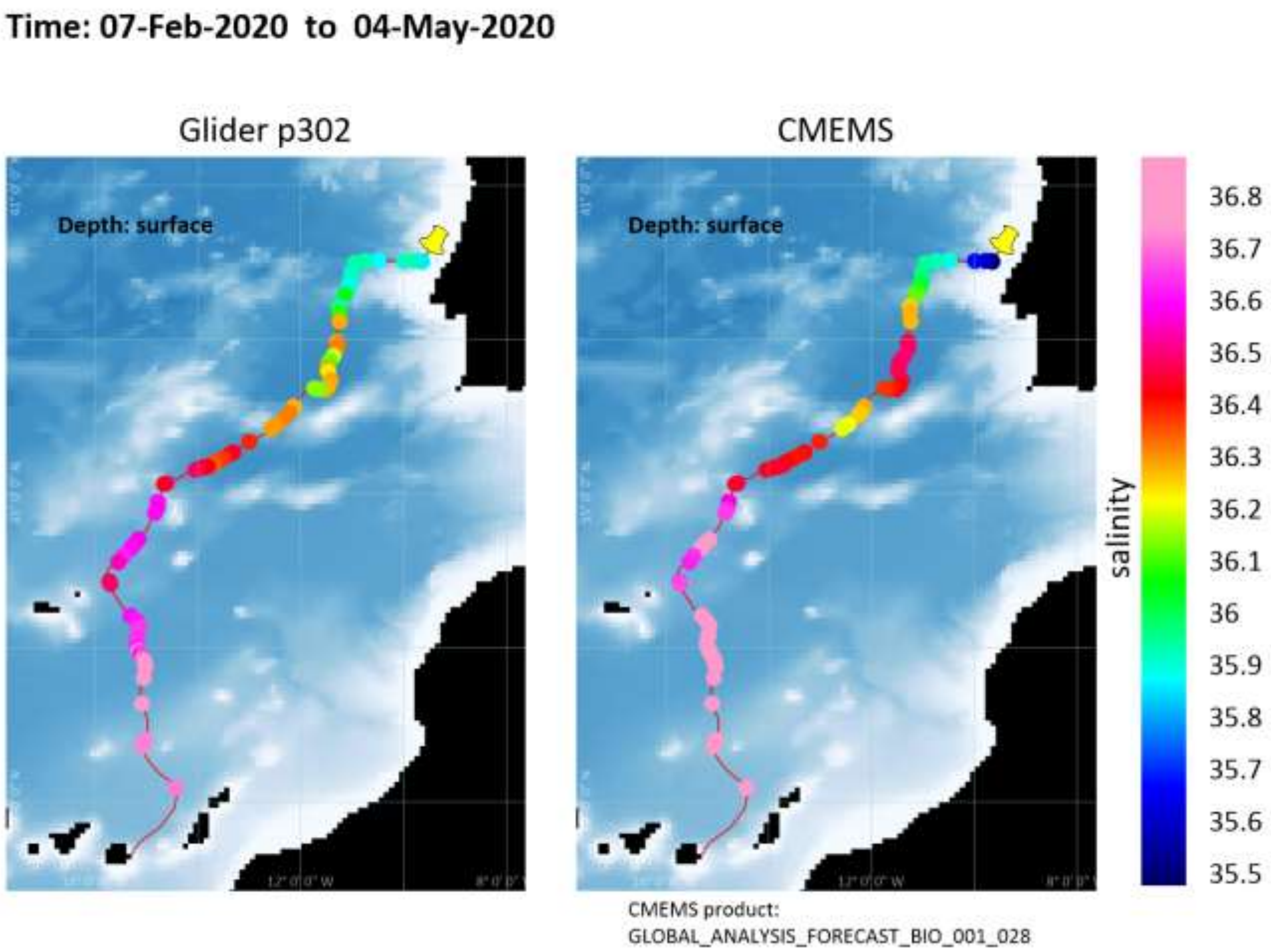
Glider: p302



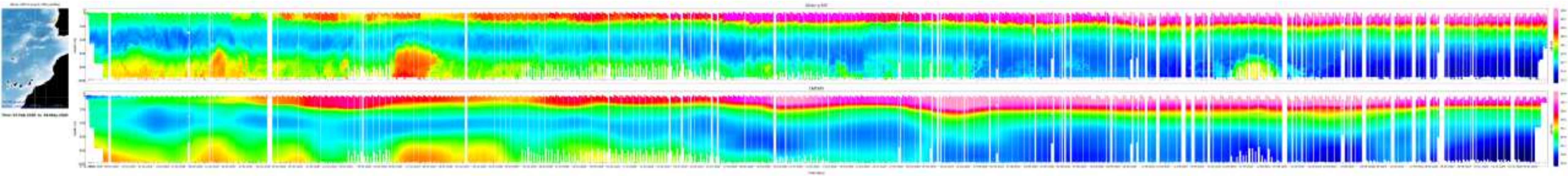
http://www.ifremer.fr/co/ego/ego/v2/

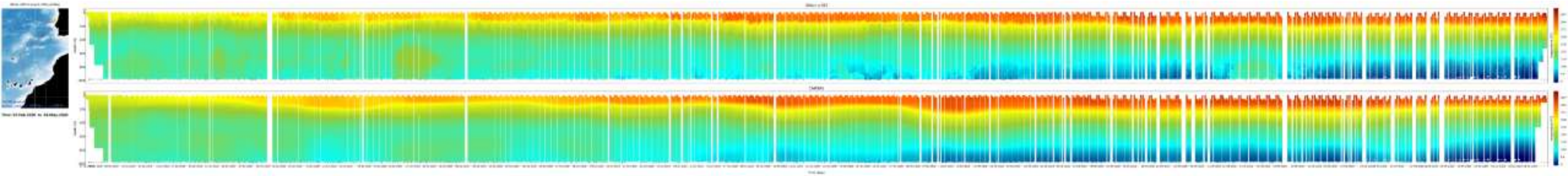
CMEMS Validation



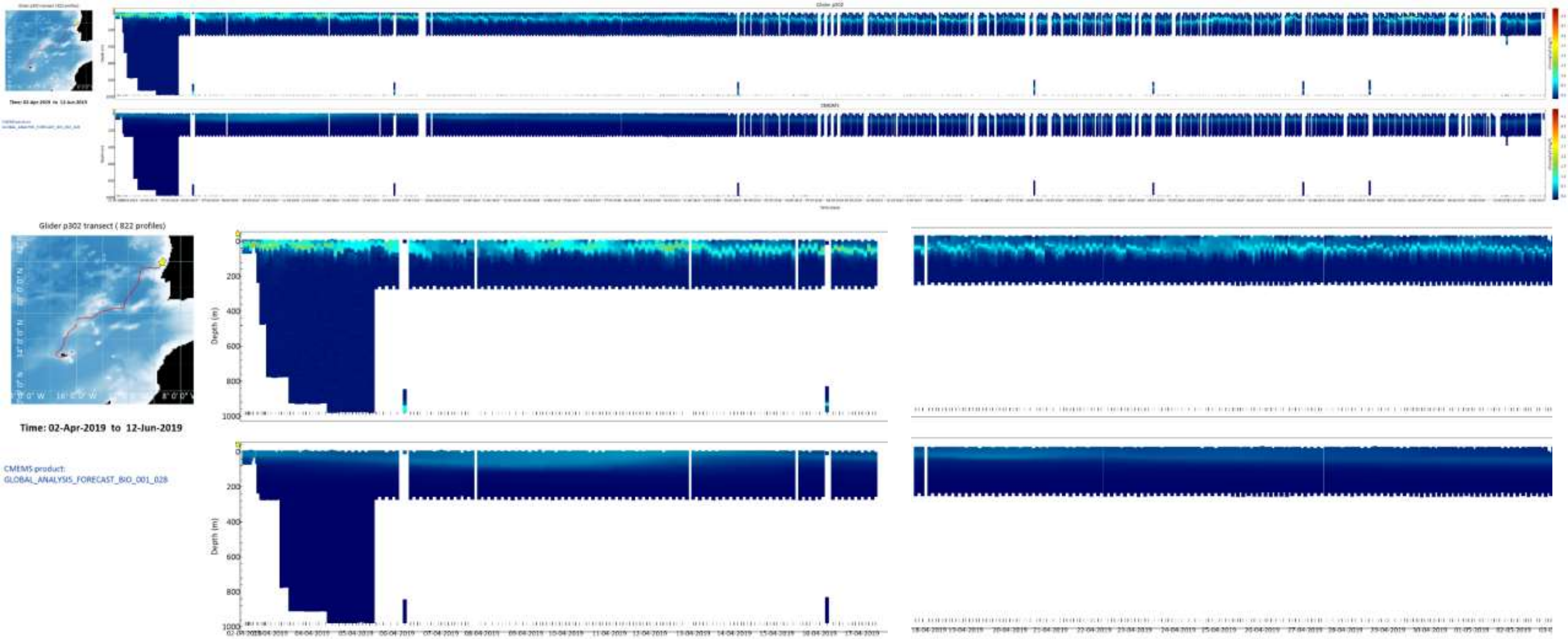


Salinity and Temperature Profiles

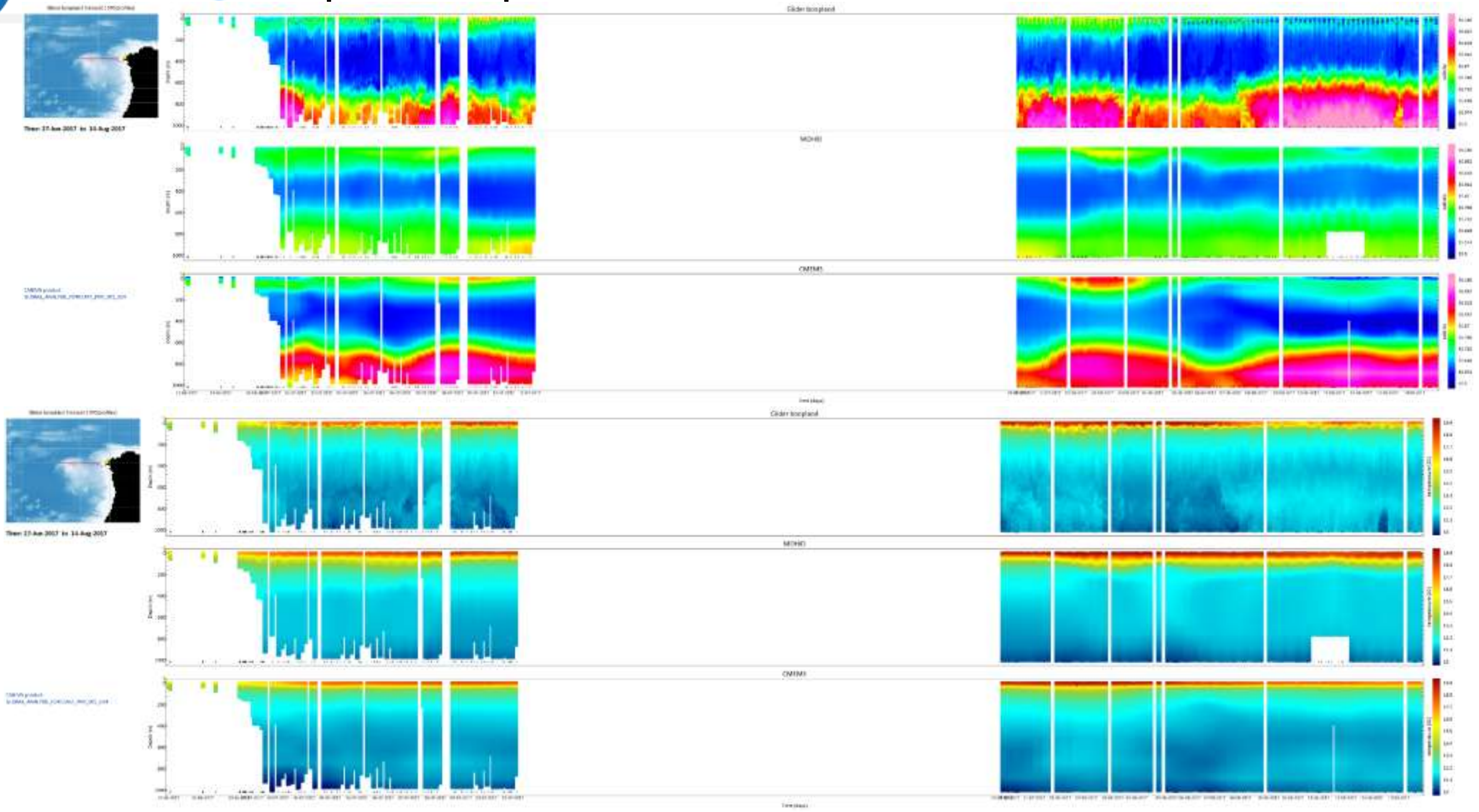




Chlorophyll Section

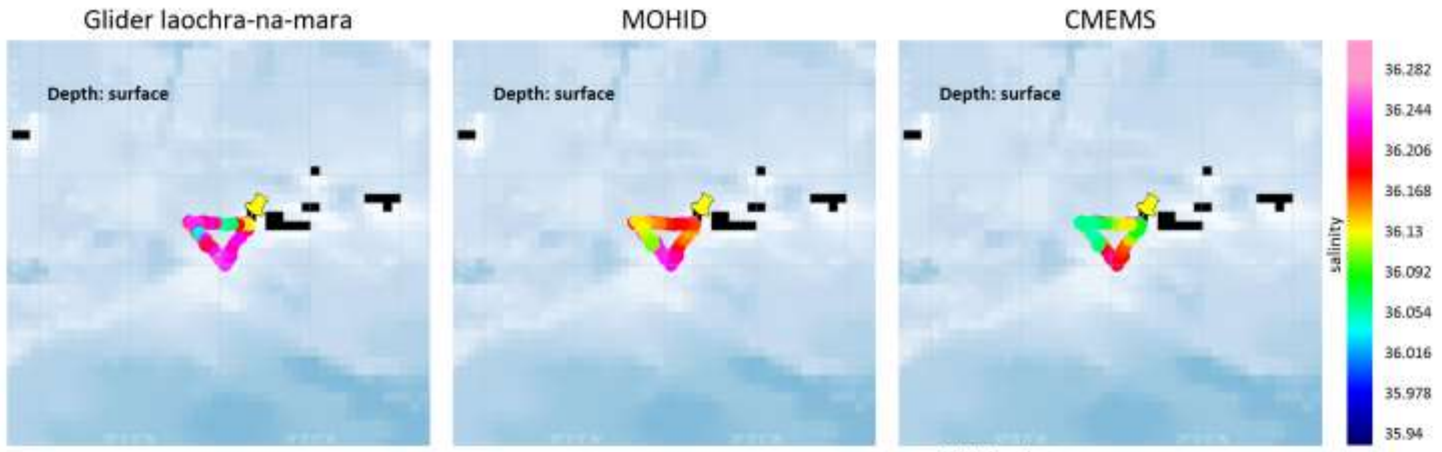


Triple Comparison

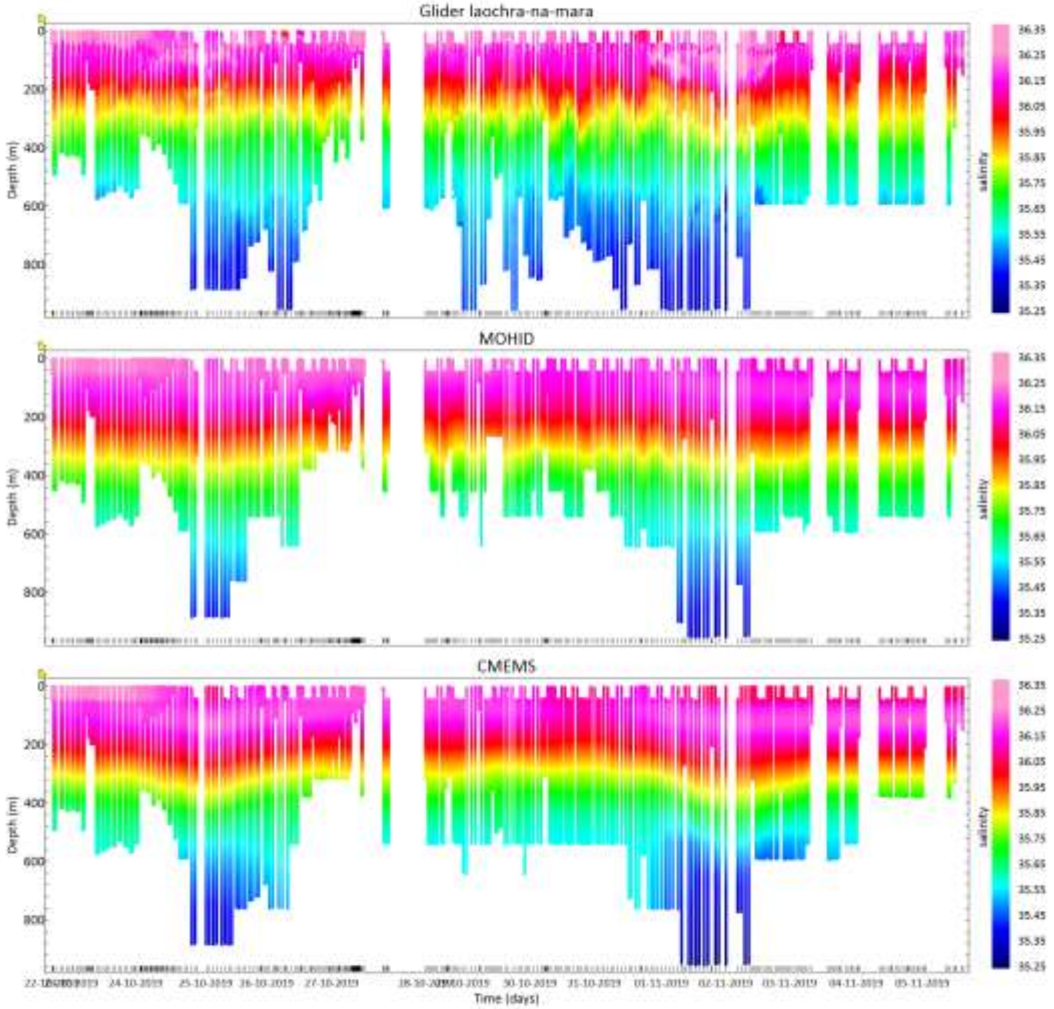


Glider Comparison Azores

Time: 22-Oct-2019 to 05-Nov-2019



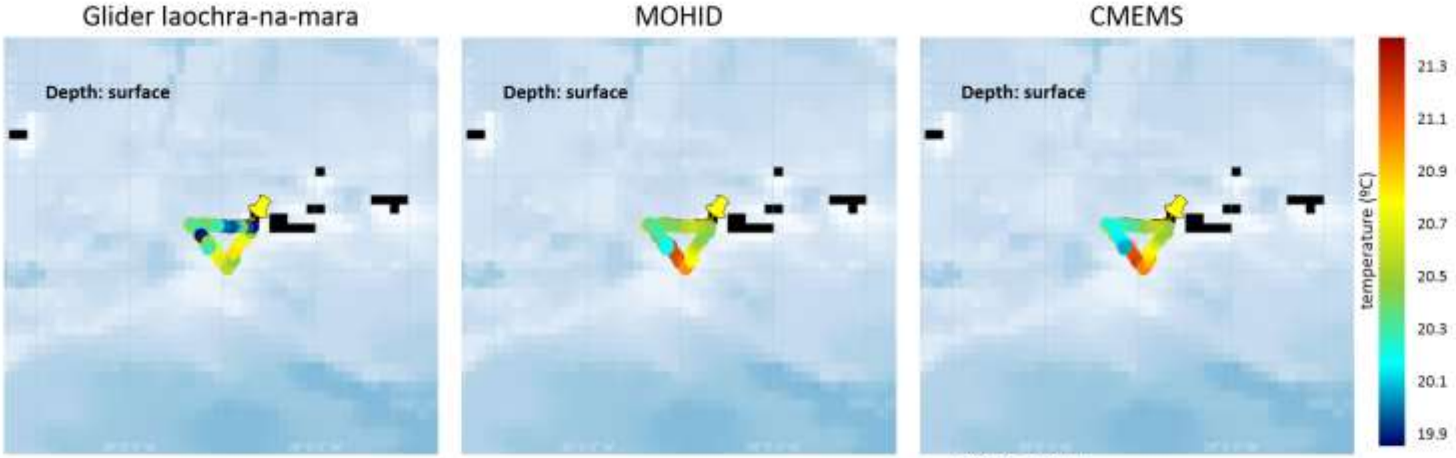
CMEMS product:
GLOBAL_ANALYSIS_FORECAST_BIO_001_028



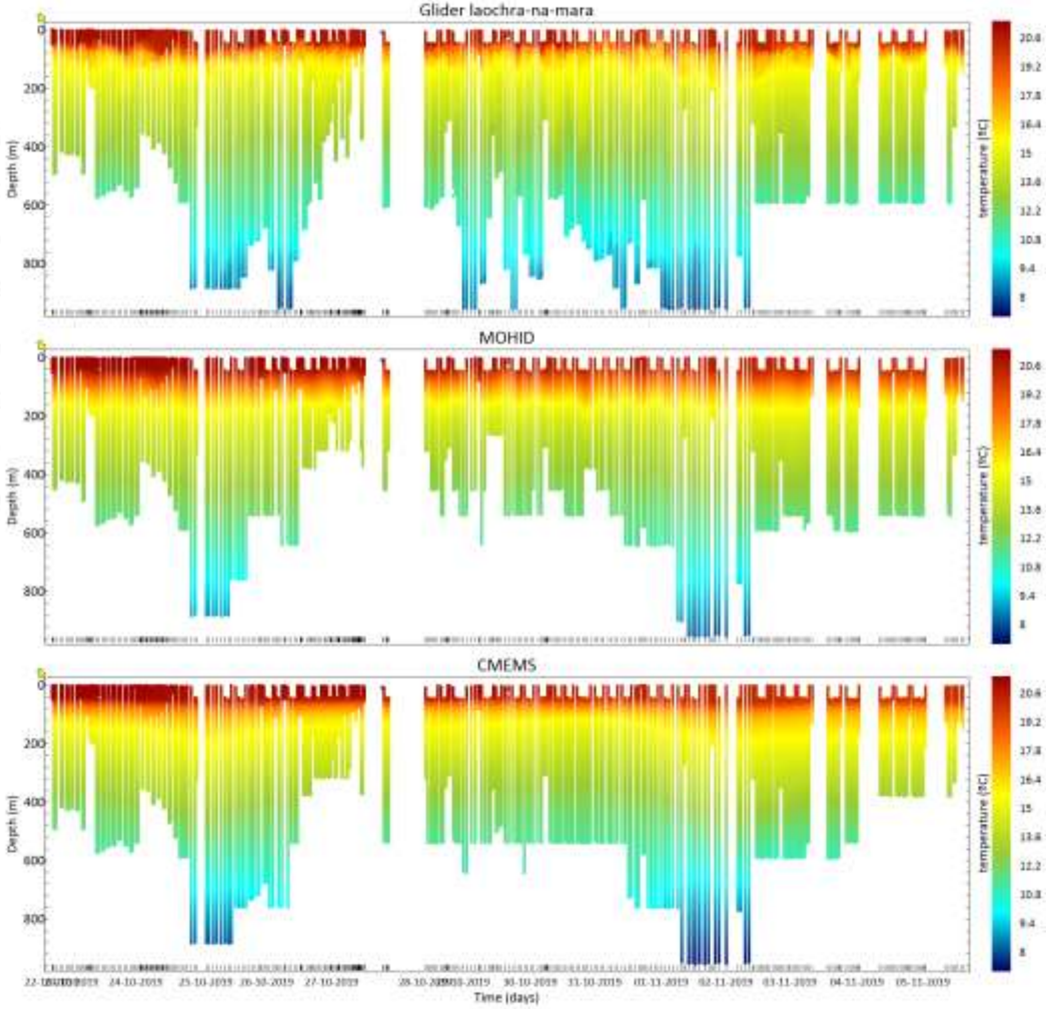
CMEMS product:
GLOBAL_ANALYSIS_FORECAST_BIO_001_028

Glider Comparison Azores

Time: 22-Oct-2019 to 05-Nov-2019

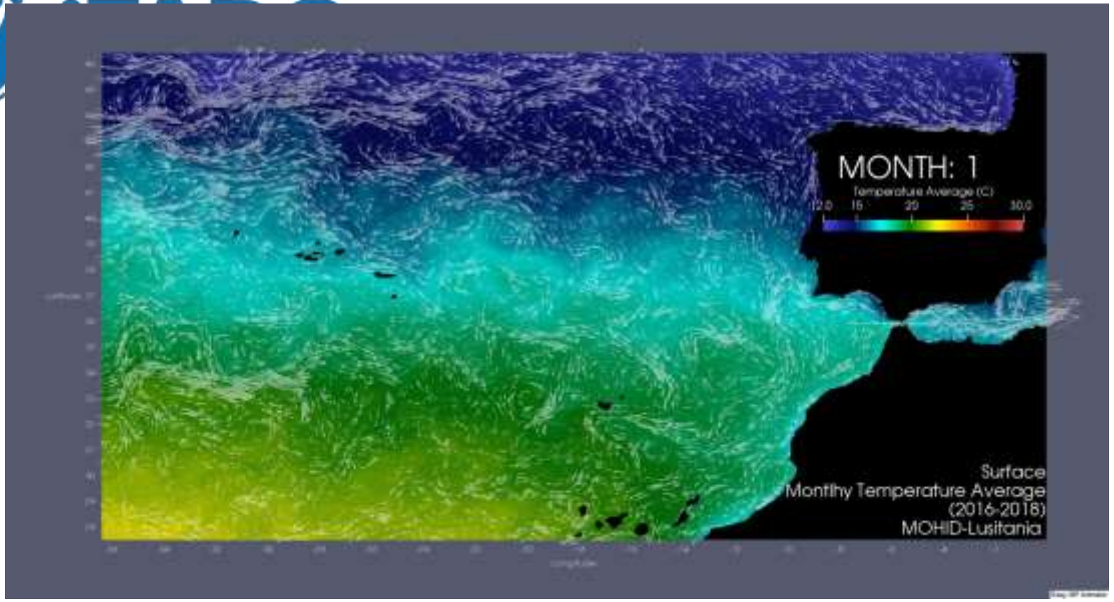


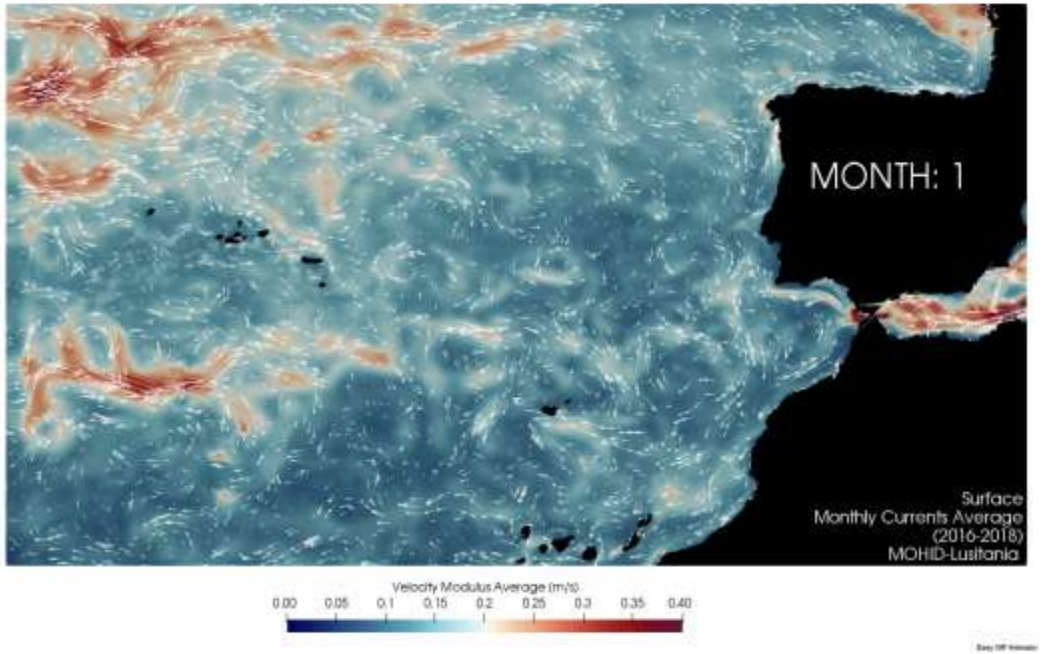
CMEMS product:
GLOBAL_ANALYSIS_FORECAST_BIO_001_028

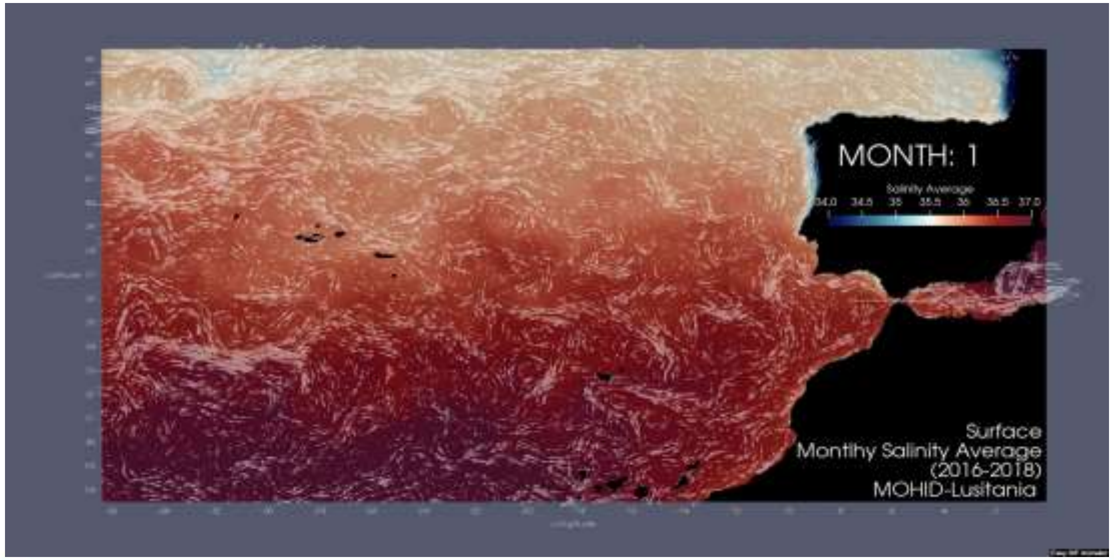


CMEMS product:
GLOBAL_ANALYSIS_FORECAST_BIO_001_028

Climatology

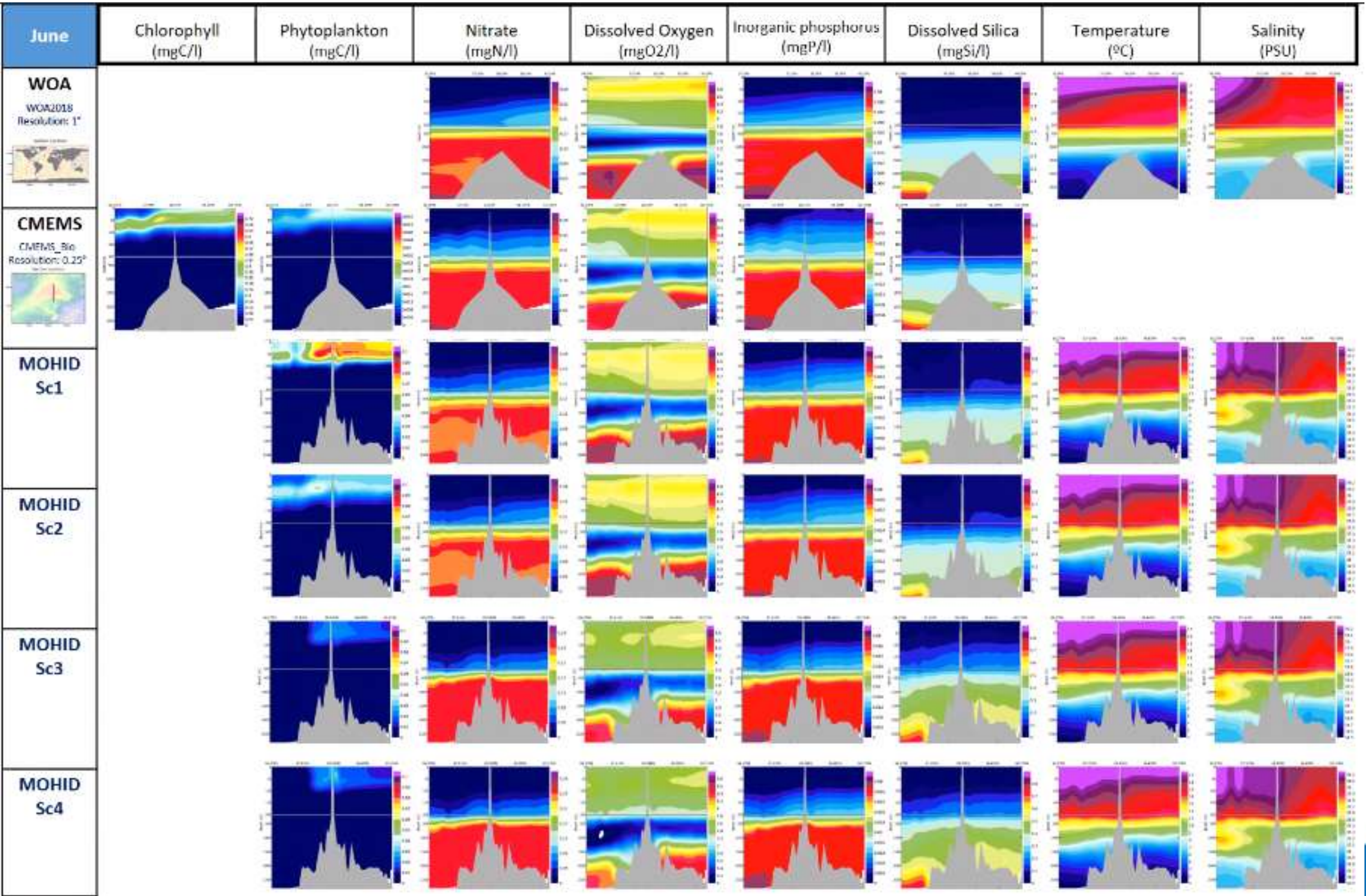

MONTH: 1
Temperature Average (C)
12.0
15
20
25
30.0
Surface
Monthly Temperature Average
(2016-2018)
MOHID-Lusitania


MONTH: 1
Surface
Monthly Currents Average
(2016-2018)
MOHID-Lusitania
Velocity Modulus Average (m/s)
0.00
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.40


MONTH: 1
Salinity Average
34.0
34.5
35
35.5
36
36.5
37.0
Surface
Monthly Salinity Average
(2016-2018)
MOHID-Lusitania

Biogeochemical model in Azores – Validation and calibration

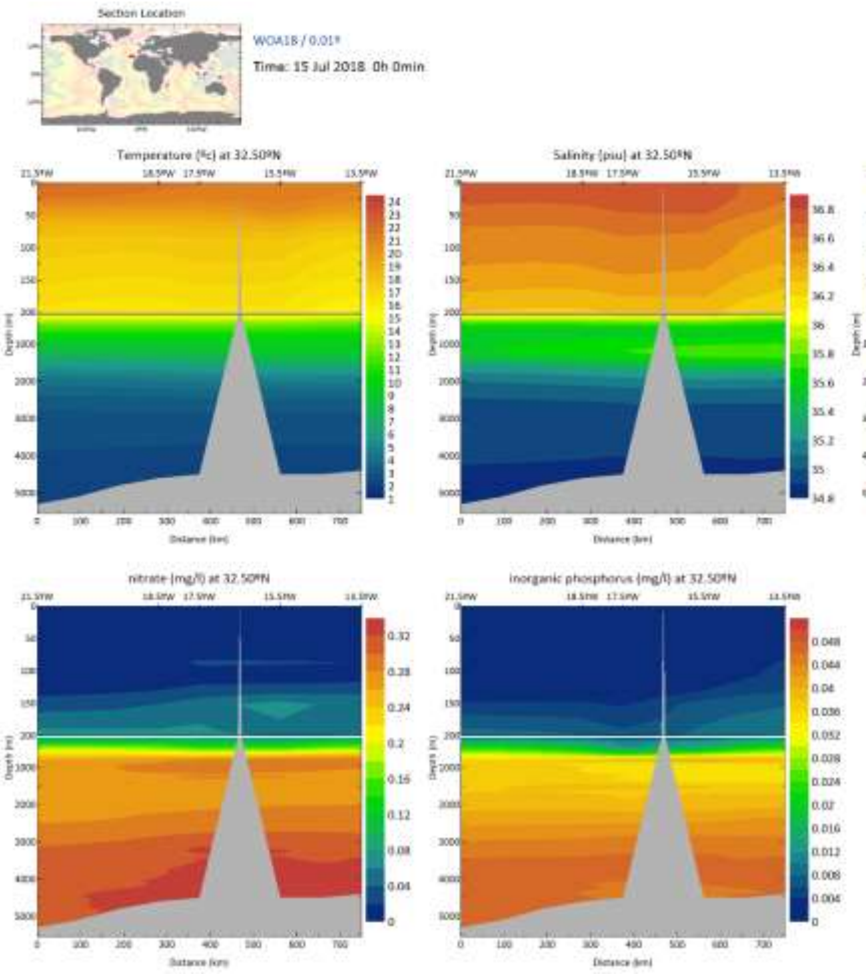
WOA and CMEMS Comparison vs MOHID

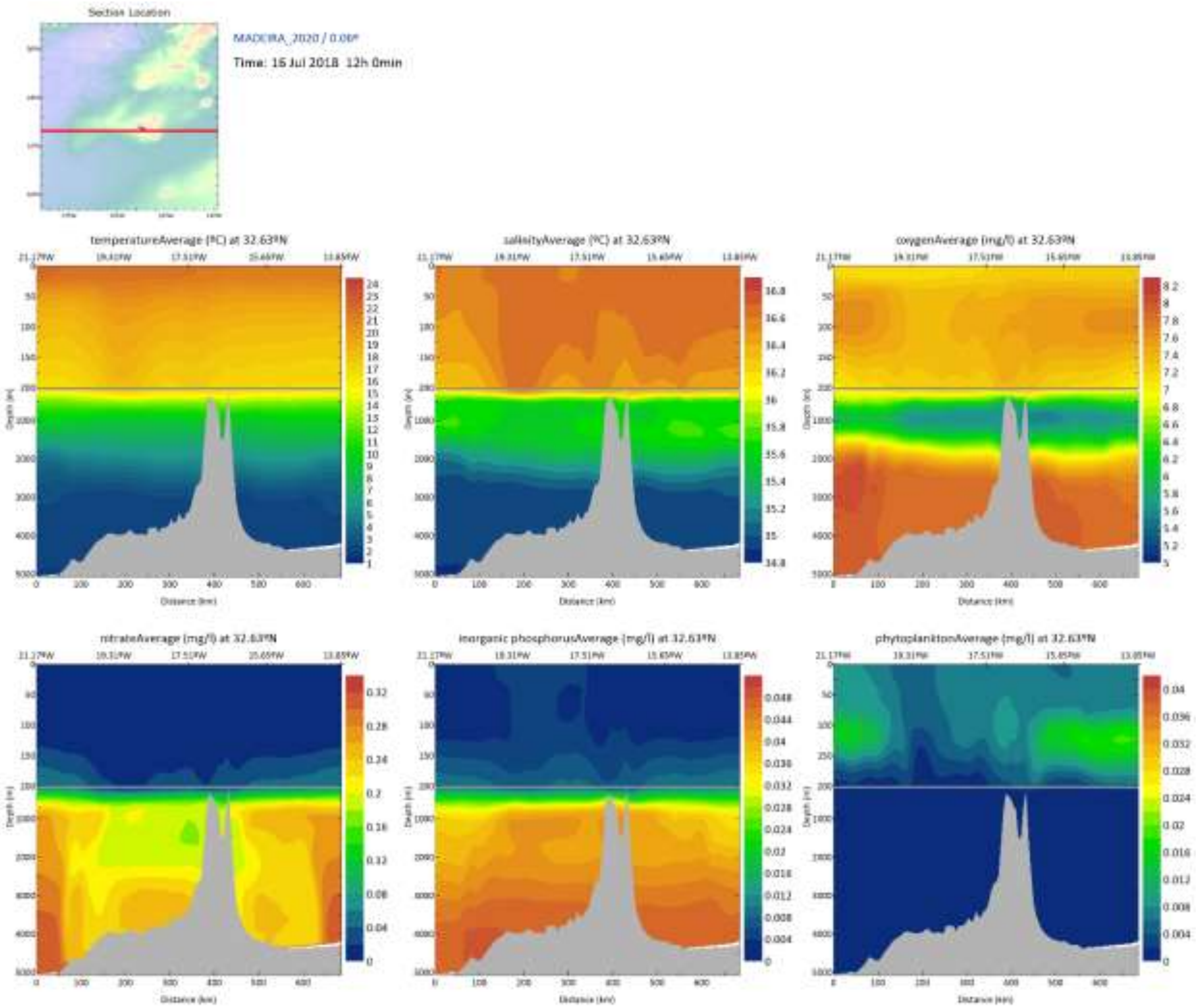


Vertical distribution of monthly average (June, 2017) for phytoplankton, nitrate, dissolved oxygen, phosphorus, silica, temperature and salinity for WOA-2018, CMEMS and different MOHID calibration scenarios.

Biogeochemical model in Madeira – Validation and calibration

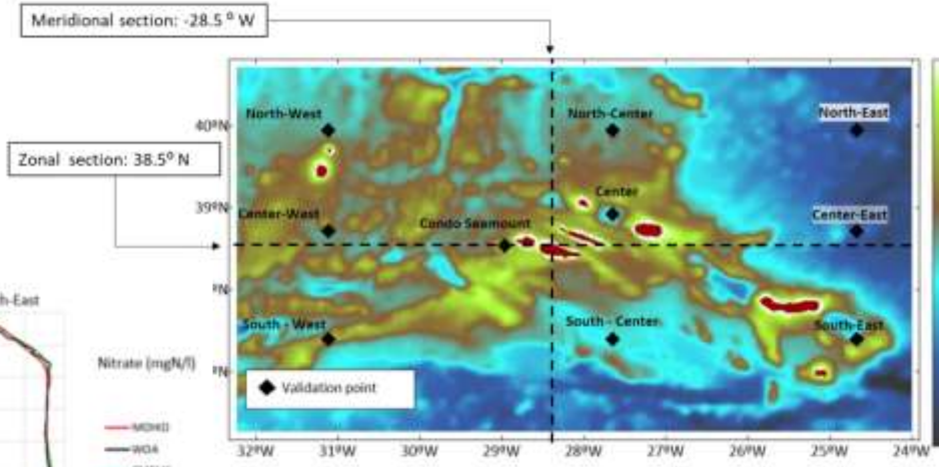
WOA Comparison vs MOHID

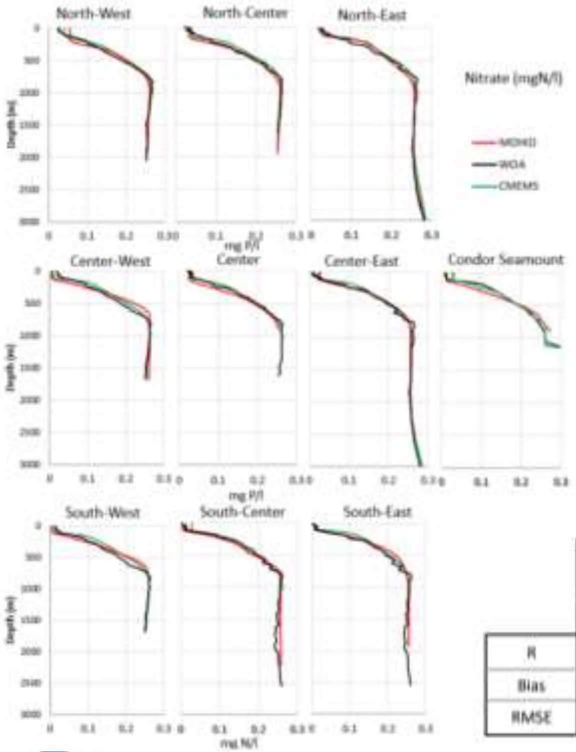


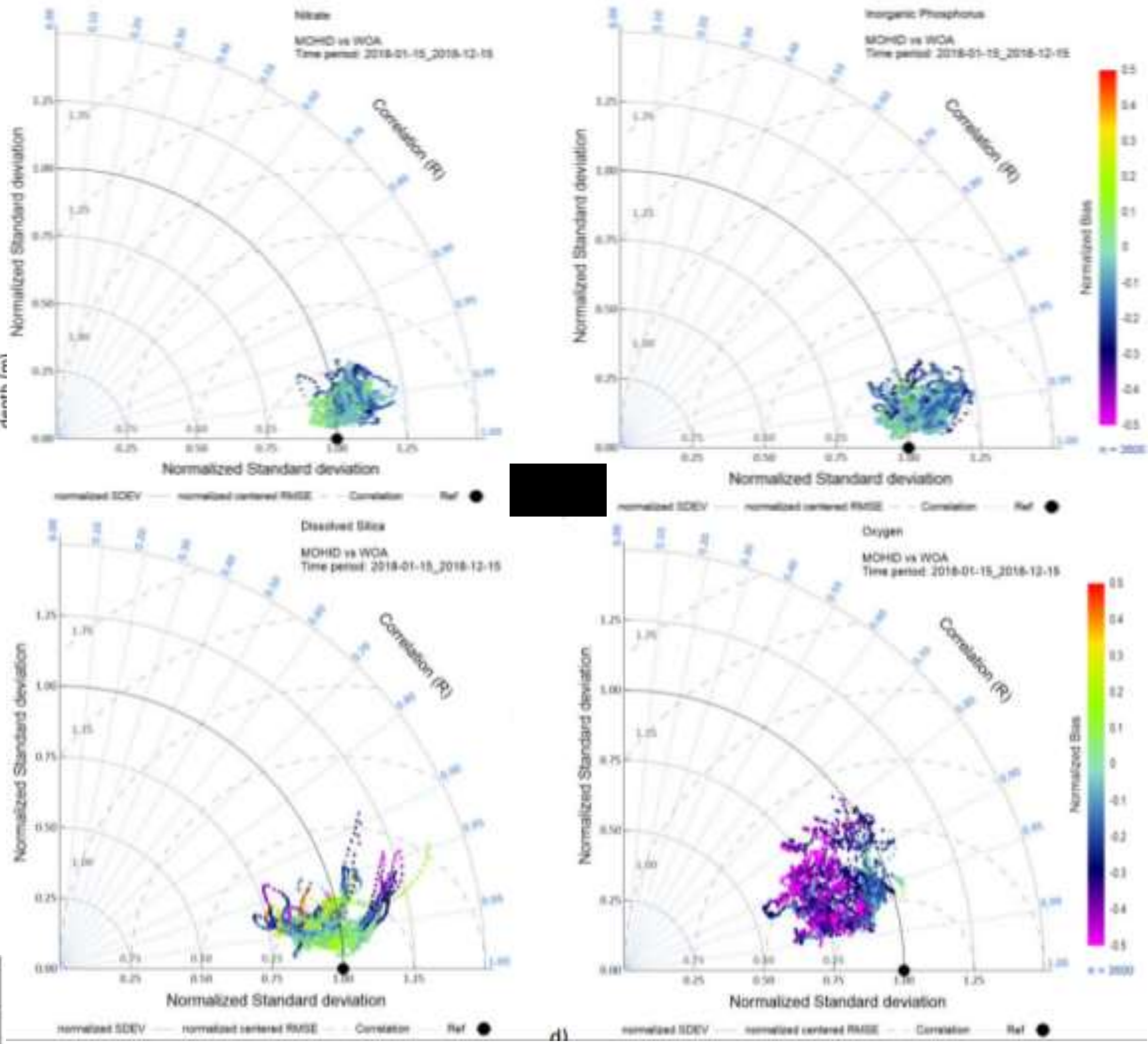


Model validation along the water column

- **Nutrients (Nitrate, Phosphate, Silicate)**
- **Dissolved oxygen**







[redacted]

	Nitrate (mgN/l)		Dissolved Silica (mgSi/l)		Inorganic phosphorus (mgP/l)		Oxygen (mgO/l)		Phytoplankton (mgC/l)
	Mohid vs WOA	Mohid vs CMEMS	Mohid vs WOA	Mohid vs	Mohid vs WOA	Mohid vs CMEMS	Mohid vs WOA	Mohid vs CMEMS	Mohid vs CMEMS
R	0.983	0.981	0.971	0.992	0.983	0.983	0.865	0.887	0.941
Bias	-0.007	-0.006	0.0	-0.01	-0.001	-0.001	-0.215	-0.035	0.001
RMSE	0.016	0.014	0.031	0.017	0.002	0.002	0.334	0.166	0.005

MSFD Indices

Same as Python-based Graphical User Interface (GUI) tool for computing MSFD from IMI

MSFD Indices

$$Deficit\ potential\ Energy = \frac{1}{H_0+\xi}\int_{-H}^{\xi}(\bar{\rho}-\rho_z)gz\,dz$$

with H the bathymetry and ξ the free surface elevation

$$Front\ index(i,j) = \frac{1}{2}max\left(\frac{Strat_{(i+1,j)}-Strat_{(i-1,j)}}{dx_{i,j}}, \frac{Strat_{(i,j+1)}-Strat_{(i,j-1)}}{dy}\right)$$

with *Strat* an index of stratification based on :

- the deficit of potential energy or
- the maximum vertical gradient of temperature, salinity, or density.

$$Eq.\ freshwater\ depth = \int_{-H}^{\xi}\frac{S_0-S_z}{S_0}dz$$

with S_0 a reference salinity

$$Okubo\ Weiss = \left(\frac{\partial u}{\partial x}-\frac{\partial v}{\partial y}\right)^2+\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)^2 - \left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)^2$$

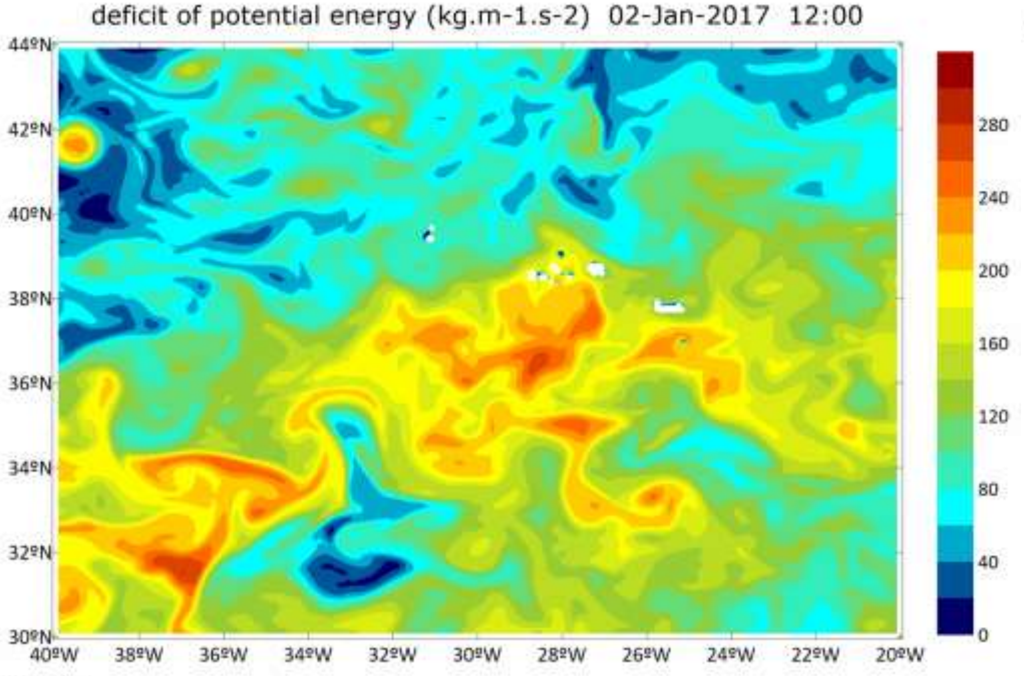
First two terms refer to the shear stress, last one refer to vorticity. Eddies are low values delineated by high values.

Stratification indices	**Surface, bottom**
Deficit of potential energy Max. vertical gradient in density Max. vertical gradient in temperature Max. vertical gradient in salinity Mixed layer depth Depth of thermocline Depth of pycnocline Depth of halocline	Temperature Salinity Density Biogeochemical properties Velocity U Velocity V Velocity modulus
Frontal indices	
Density front from Deficit in pot. Energy Density front from Max. vertical gradient Thermal front from Max. vertical gradient Haline front from Max. vertical gradient	
Plume indices	
Equivalent freshwater depth	
Eddy indices	
Vorticity (at 10m depth) Okubo-Weiss (at 10 m depth)	
Upwelling indices	
Integrated vertical velocities	

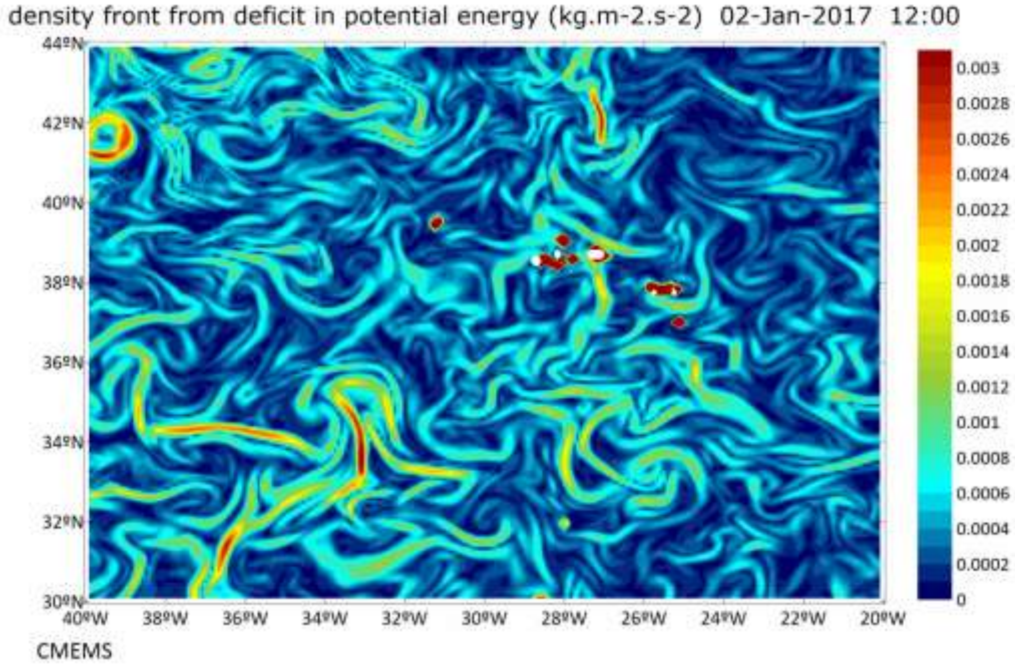
Huret M. et al. (2009), Planque, Lazure, and Jegou (2006)

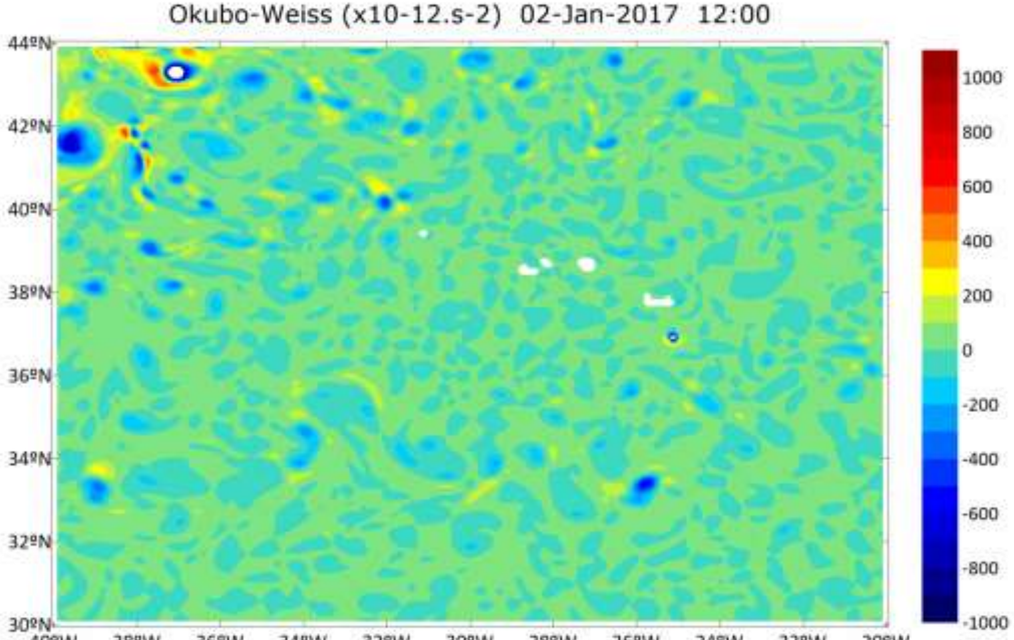
MSFD indices

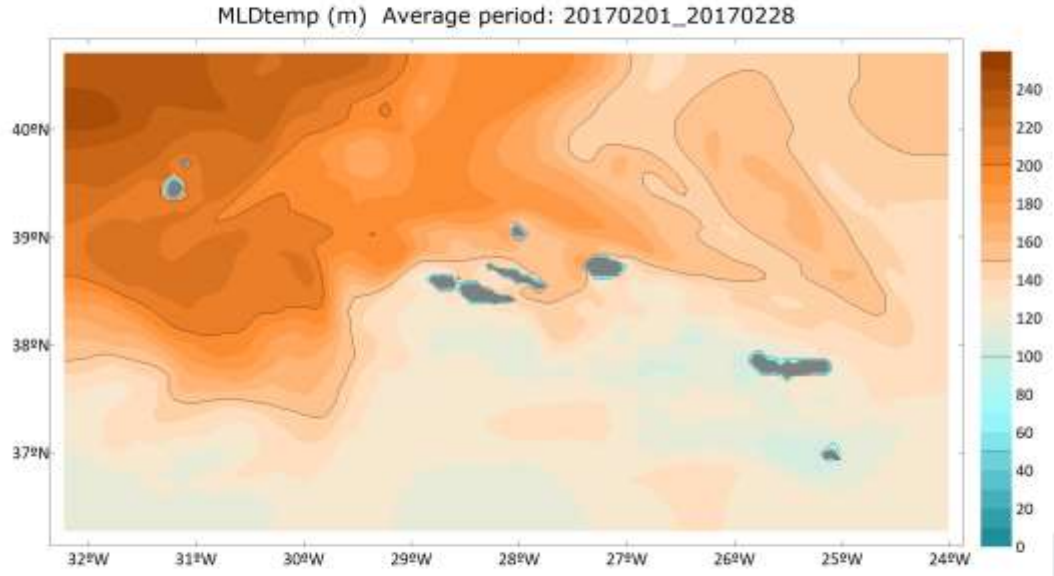
Stratification



Frontal



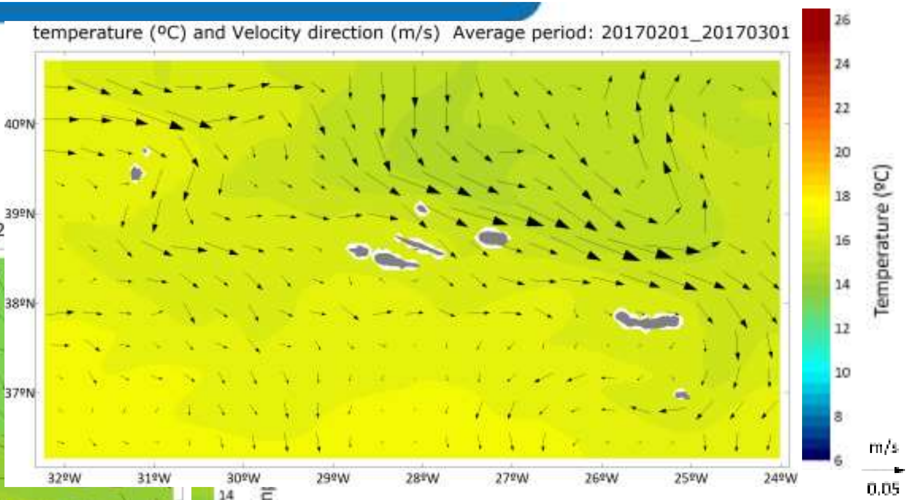




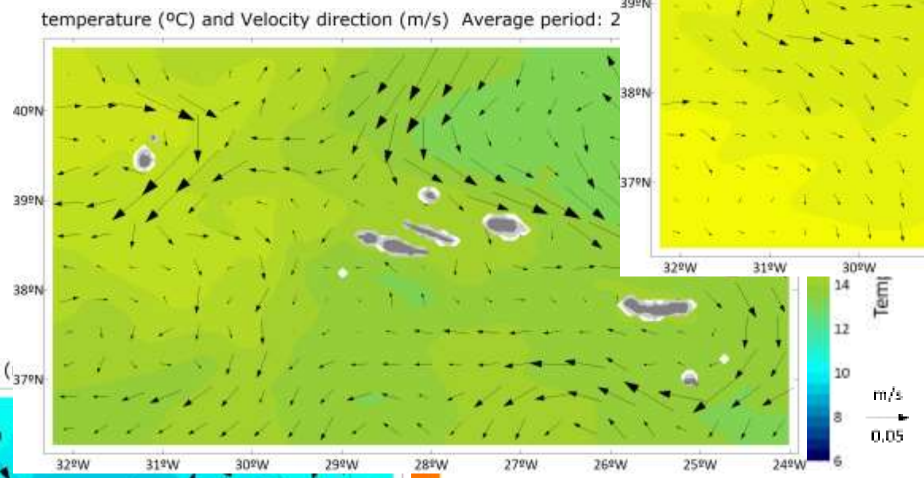
MSFD indices

iFADO

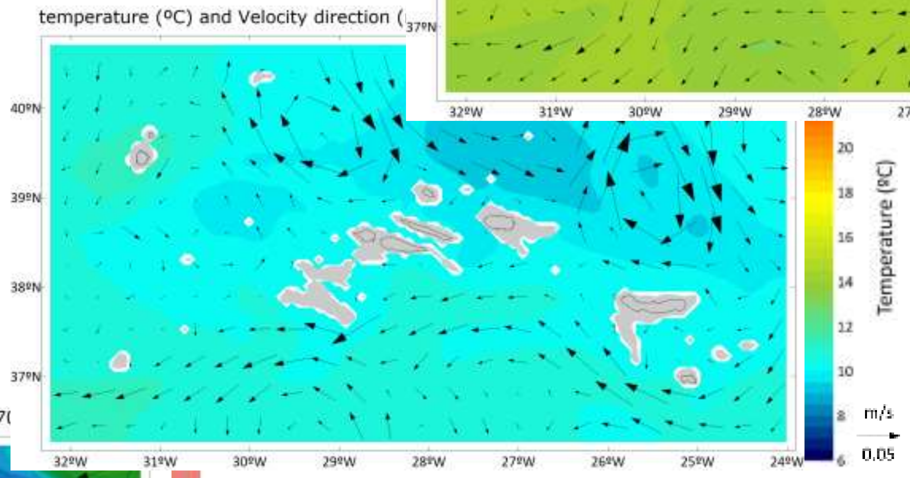
- Water properties results:
  - **Temperature**
  - Salinity
  - Density
- Hydrodynamic results:
  - Velocity modulus
  - Velocity direction
- 3D results:
  - from surface up to bottom floor



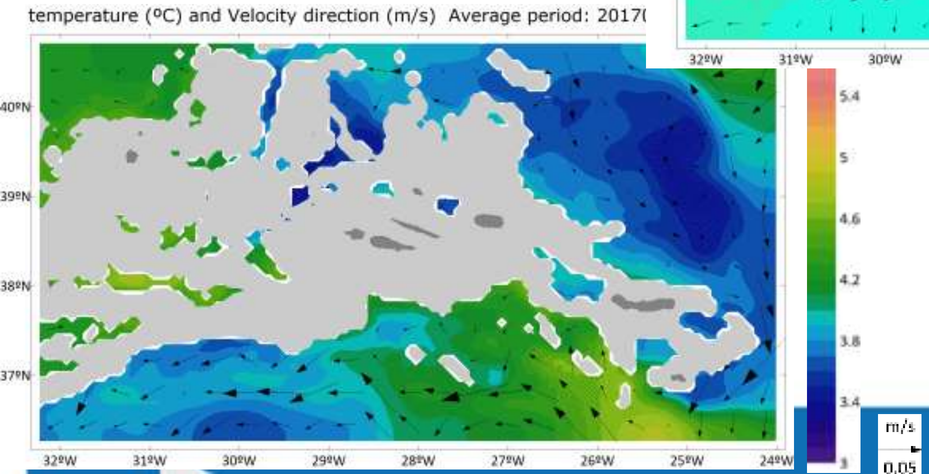
Surface



250m depth



750m depth

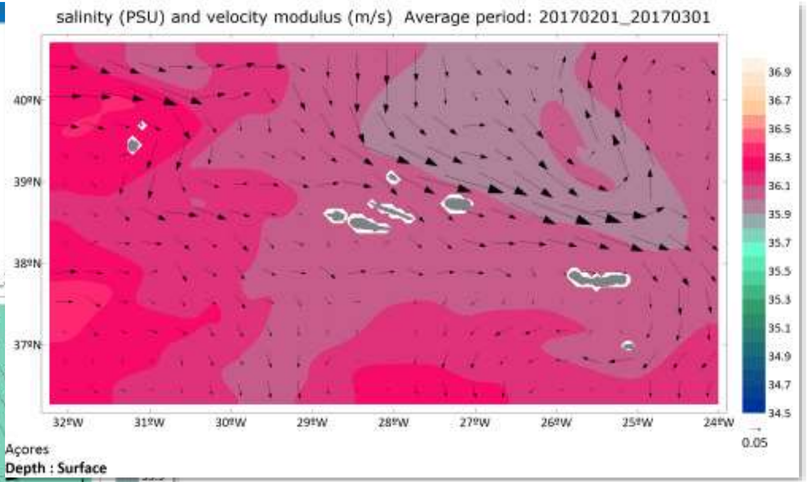


2000m depth

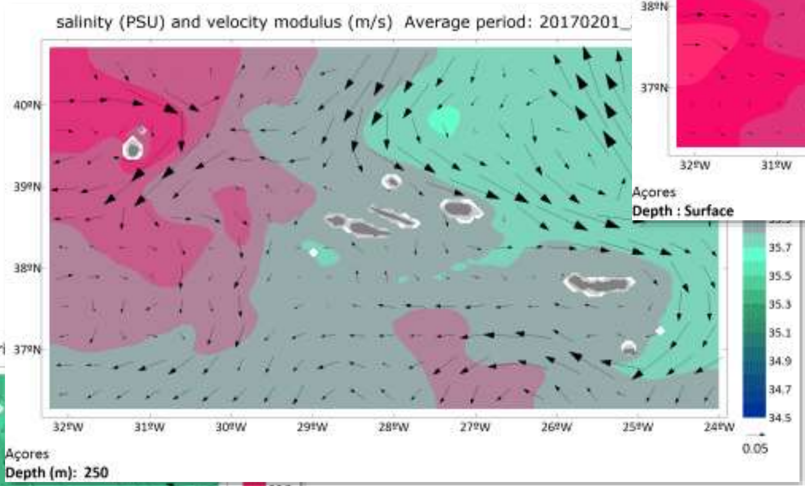
MSFD indices

- Water properties results:
  - Temperature
  - **Salinity**
  - Density
- Hydrodynamic results:
  - Velocity modulus
  - Velocity direction
- 3D results:
  - from surface up to bottom floor

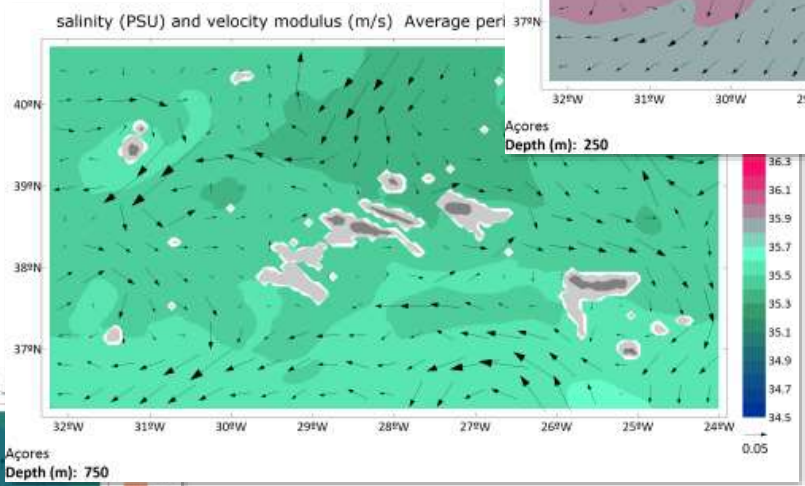
Surface



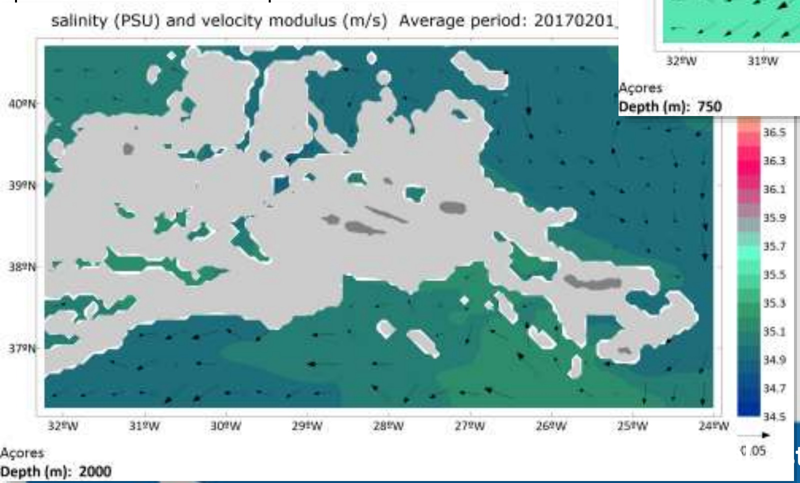
250m depth



750m depth

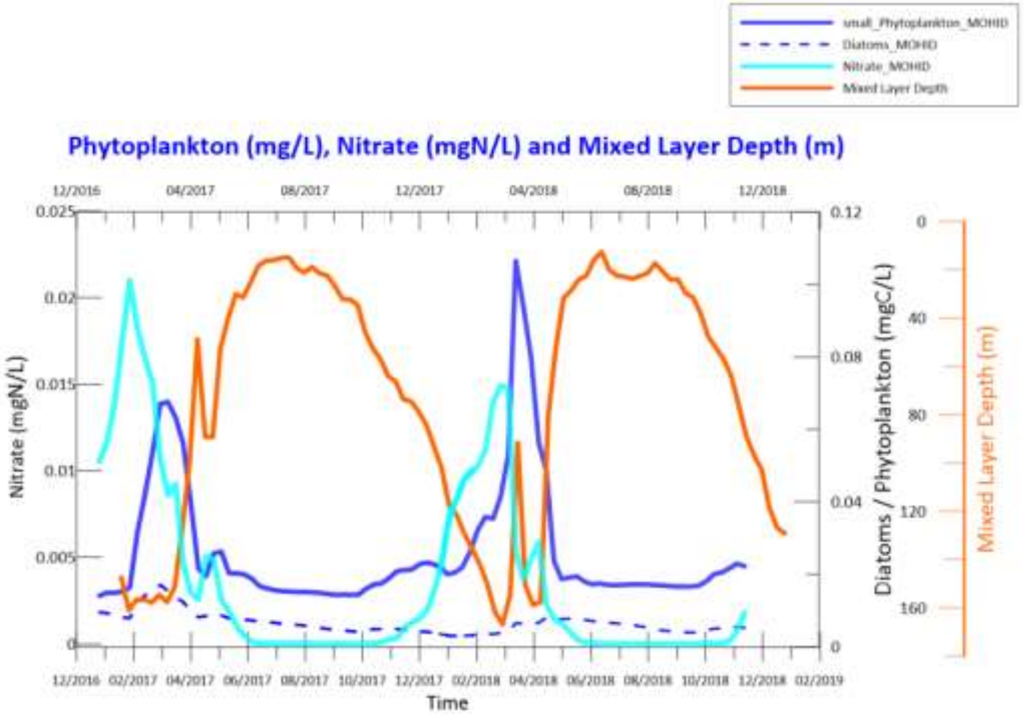


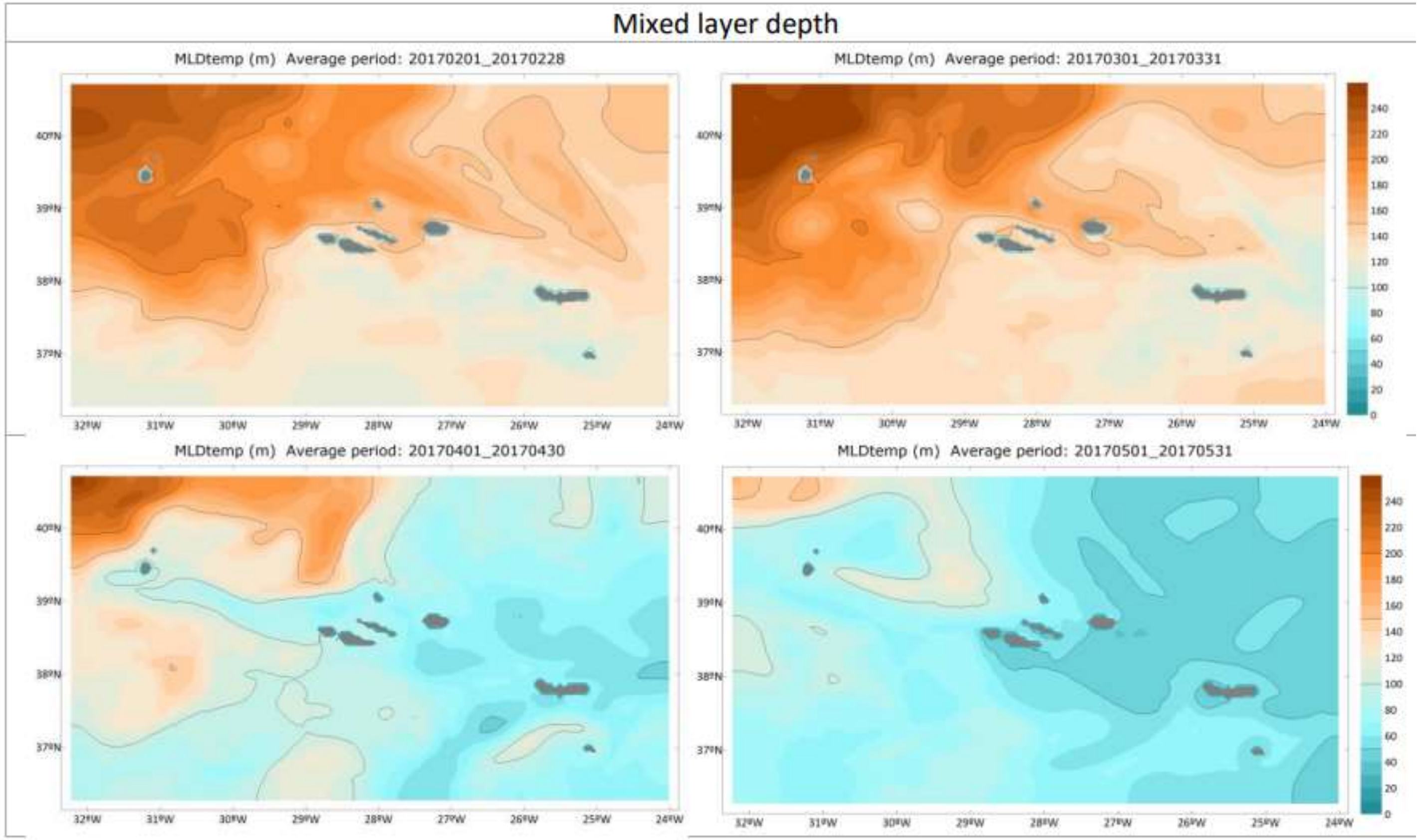
2000m depth



MSFD indices

Biogeochemical model - Mixed layer Depth and nutrients (MLD) dynamics





Mixed layer dynamics act directly, on the nutrient supply, on the availability of light, and consequently, on phytoplankton dynamics (Doney et al., 2001)

iFADO
INNOVATION IN THE FRAMEWORK OF THE ATLANTIC DEEP OCEAN

Thank you !

Interreg
Atlantic Area
European Regional Development Fund
EUROPEAN UNION

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