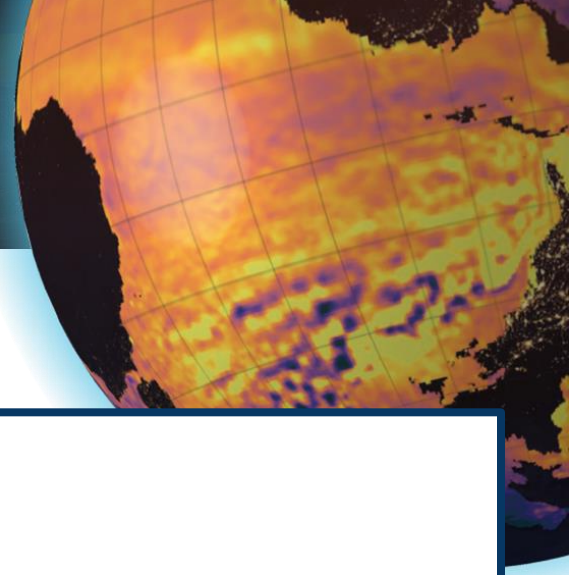
Integrating BGC-Argo predicted profiles via Convolutional Neural Networks into the Data Assimilation of the Copernicus Mediterranean biogeochemical model

Carolina Amadio,
Anna Teruzzi, Pietropolli Gloria, Manzoni Luca, Gianpiero Cossarini

Outline



Background:

- MedBFM model system
- BGC-Argo Observational dataset
- Neural Network based dataset (1D PPCon)

Methods & Results

- Observing System Experiment

Conclusions

MedBFM model system

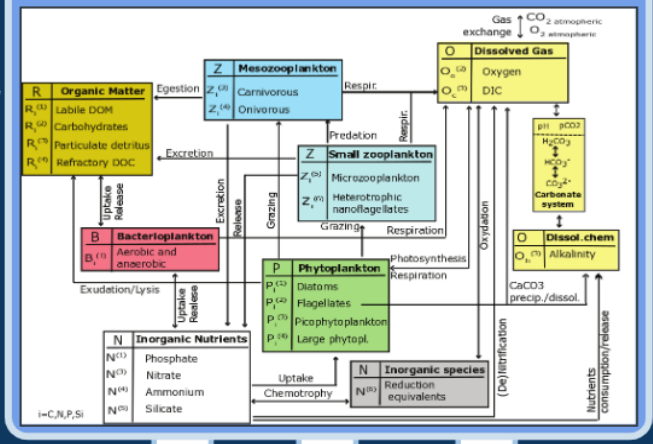
Offline coupled with Nemo OceanVAR (Physics)

OASIM: ocean-atm spectral irradiance

OGSTM: transport model. Resolution 1/24°, 141 z levels

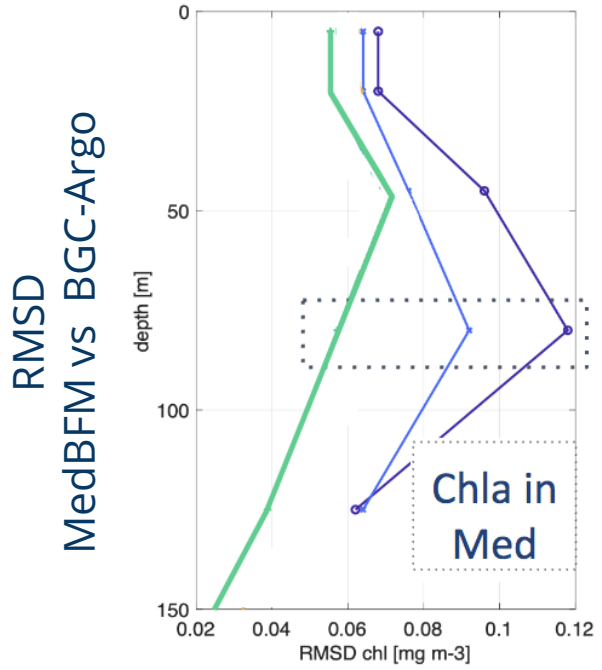
3DVar-Bio Assimilation: Ocean Colour (weekly) and BGC Argo Chla, NO_3, O_2 (daily) + NN predicted NO_3

BFM: Biogeochemical Flux Model



- Short-terms (analysis & forecast)
- Long-terms products (reanalysis)

3DVar-Bio data assimilation evolution MedBFM



The BGC-Argo assimilation has a positive impact on the representation of the chla vertical structure (in particular in the deep chla maximum, DCM)

No BGC-ARGO DA (before 2018)

BGC-ARGO DA of Chla NO3 (2018)

BGC-ARGO DA of Chla NO3 and O2 (2021)

Research Goal

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BFM: Biogeochemical Flux Model

- Short-terms (analysis & forecast)
- Long-terms products (reanalysis)

3DVar-Bio data assimilation evolution MedBFM

Data Assimilation of BGC-Argo chlorophyll and nitrate

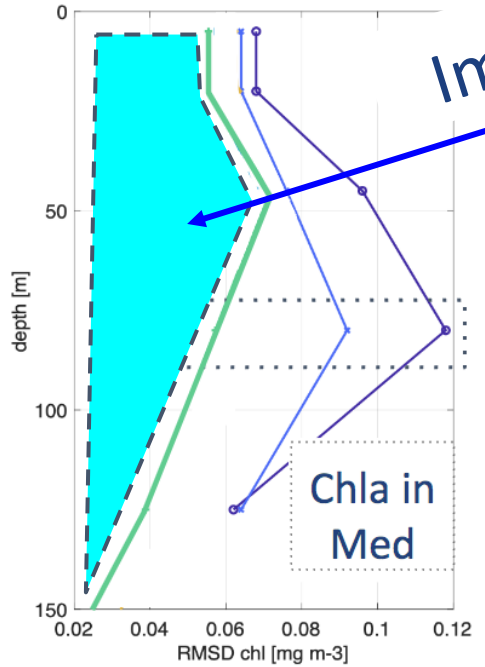
Data Assimilation of BGC-Argo oxygen

Neural network and Data Assimilation

2014 2015 2018 2020 2021 2022 2024

Improvements?

RMSD MedBFM vs BGC-Argo



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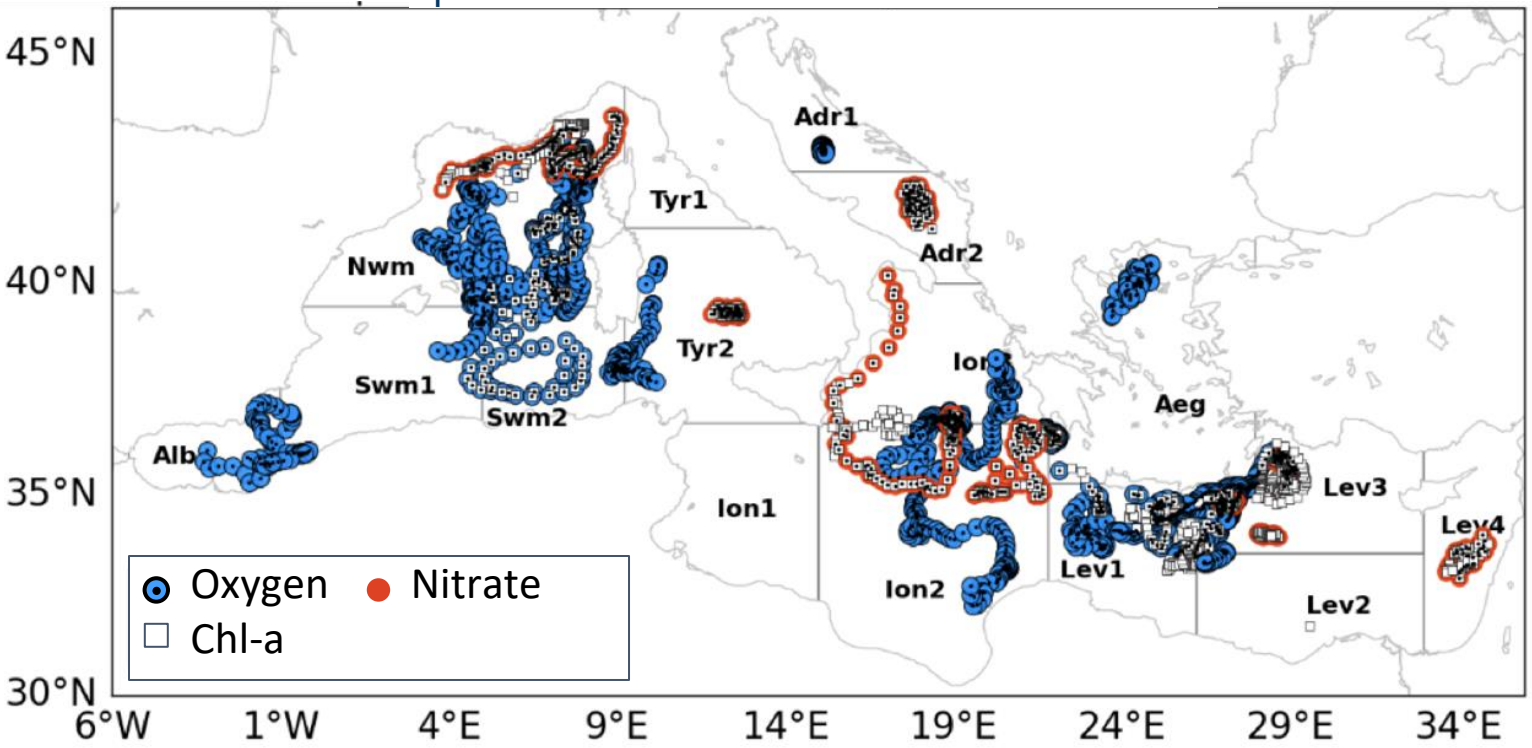
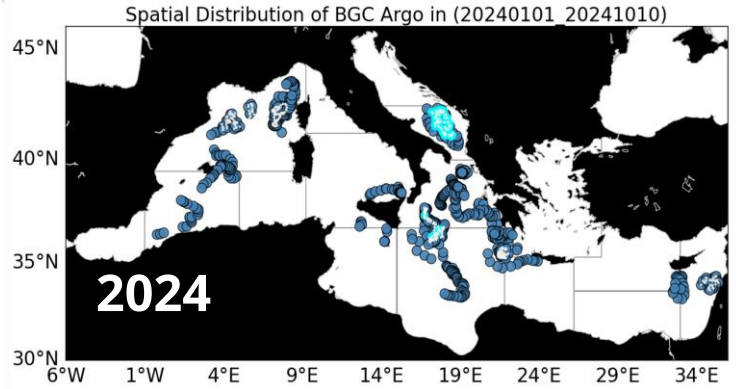
The BGC-ARGO dataset

Spatial distribution of BGC-ARGO in 2019



Yearly BGC-Argo availability

yr	O2	Chla	NO3
2019	2049	1167	610
J-S 2024	720	400	40



Some areas/seasons remain undersampled

The 1D NN dataset

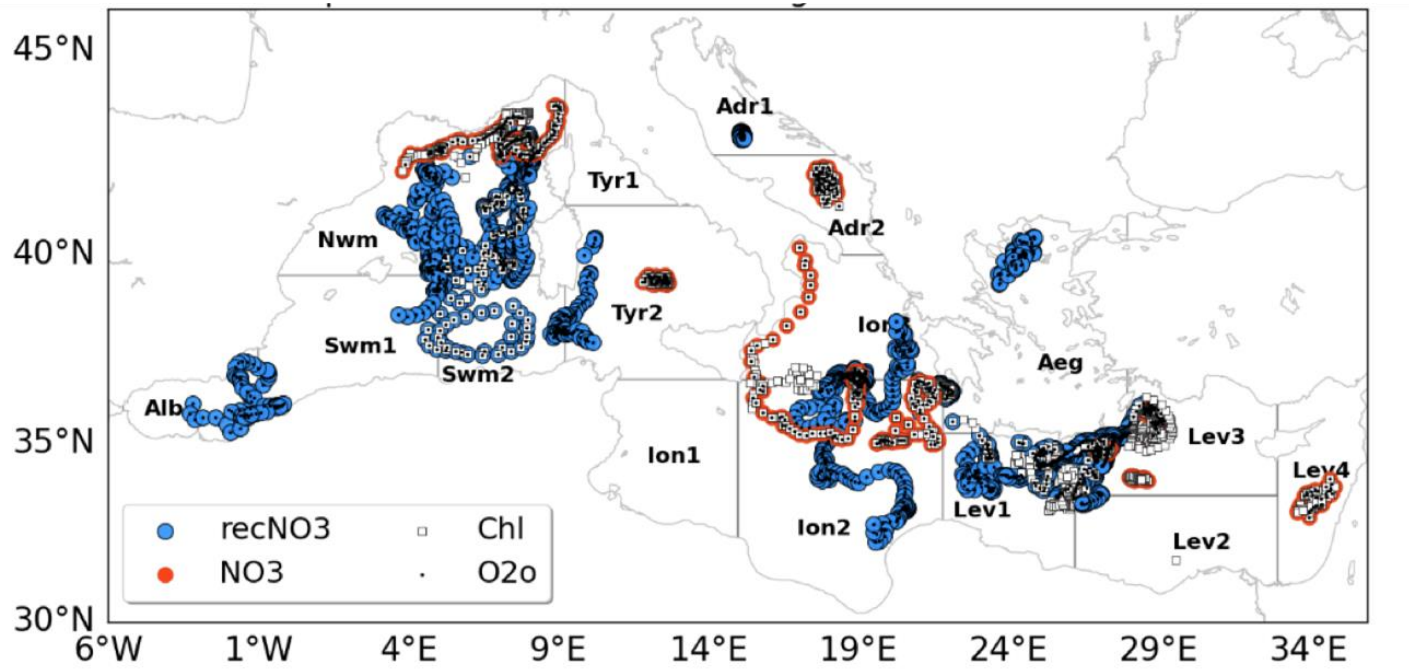
PPCon 1D (NN)

Profiles Prediction Convolutional Neural Network model to predict the shape of NO3, Chla and BBP700 vertical profiles starting from:

1. *date*
2. *geolocation*
3. *profiles of temperature*
4. *profiles of salinity*
5. *profiles of oxygen*

PPcon infers the complete BGC vertical profile
From Pietropolli et al., 2024

Spatial distribution of BGC-ARGO and PPCon Nitrate in 2019



>2000 Nitrate PPCon profiles!

Some areas/seasons remain still undersampled

(Hereafter referred to as PPCon)

The Observing System Experiment setup

Data assimilation setup for runs yr 2019

Name run	Sat_OC	BGC-ARGO	PPCon
Hindcast	no	no	no
DA_SAT	yes	no	no
DA_SATFLOAT	yes	yes	no
DA_SATFLOAT_ppcon	yes	yes	yes

- Only Nitrate PPCon is assimilated as PPCon variable.

In situ and PPCon Nitrate uncertainties (mmol m-3)

Nitrate error in situ	PPCon Nitrate error
0.24	0.44, 0.69, 0.61 (*)

Where 0.24 mmol m-3 observation error from Mignot et al., 2019

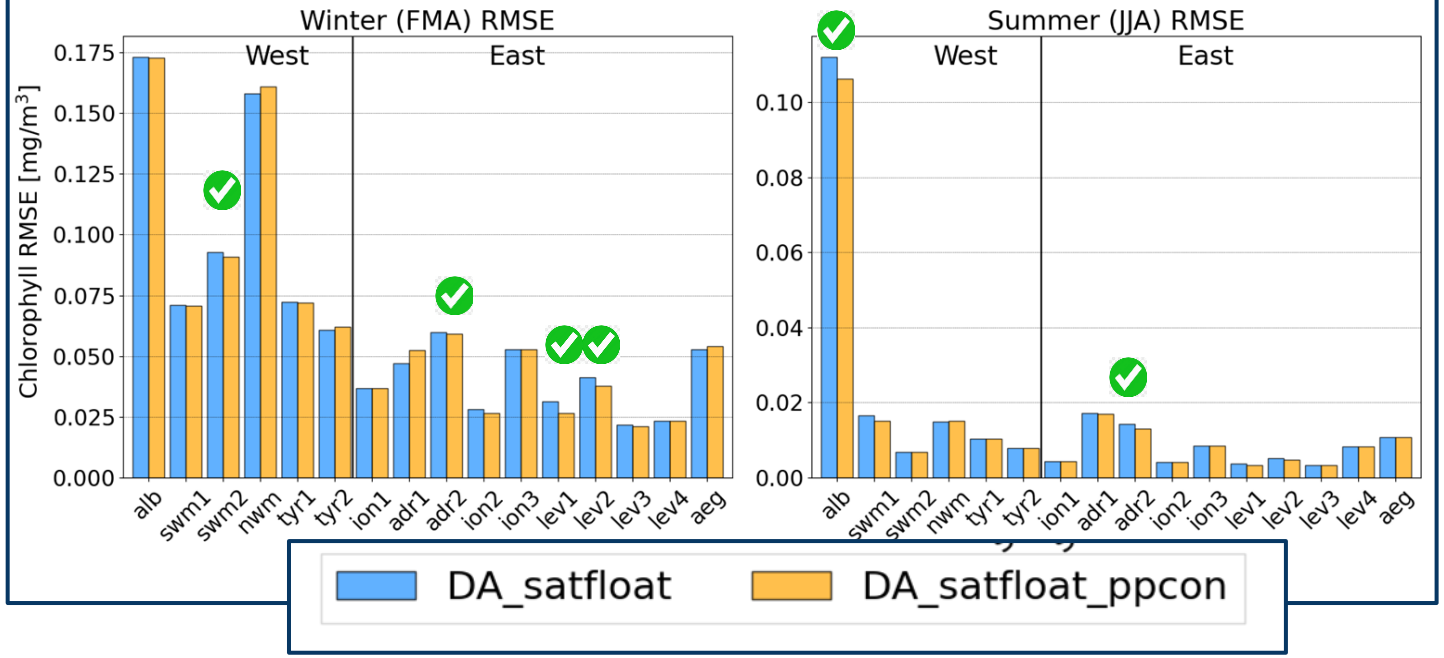
(*) PPCon_NitrateError = $\sqrt{0.24^2 + PPCon\_err^2}$ from Desroziers et al., 2005

(*) 3 values per 3 layers: 0-200 200-400 400-600m

Results: OSE validation (vs satellite)

DA_SATFLOAT vs DA_SATFLOAT_ppcon to test the impact of assimilating NO3_PPCon in Chla surface

Seasonal RMSE model-satellite (Chla at surface)



Assimilation of PPCon Nitrate leads to improvements in surface phytoplankton dynamics

Results: OSE validation (vs satellite)

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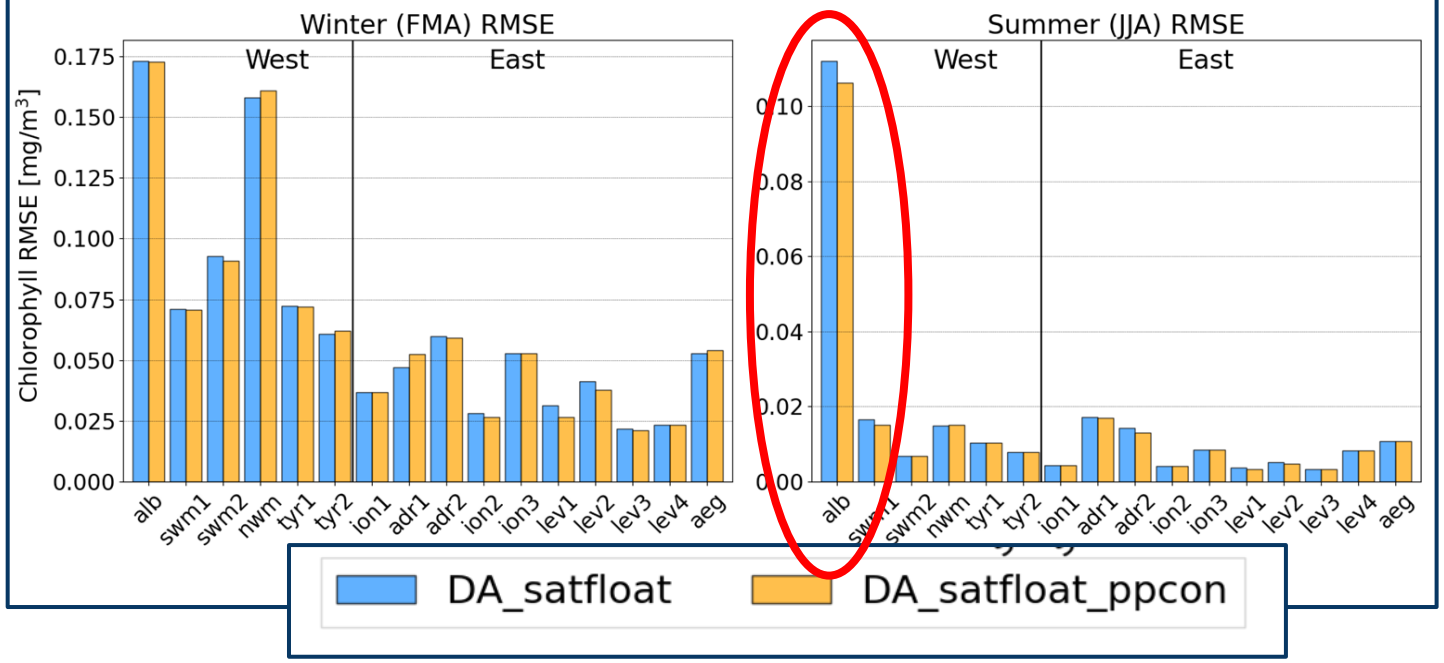
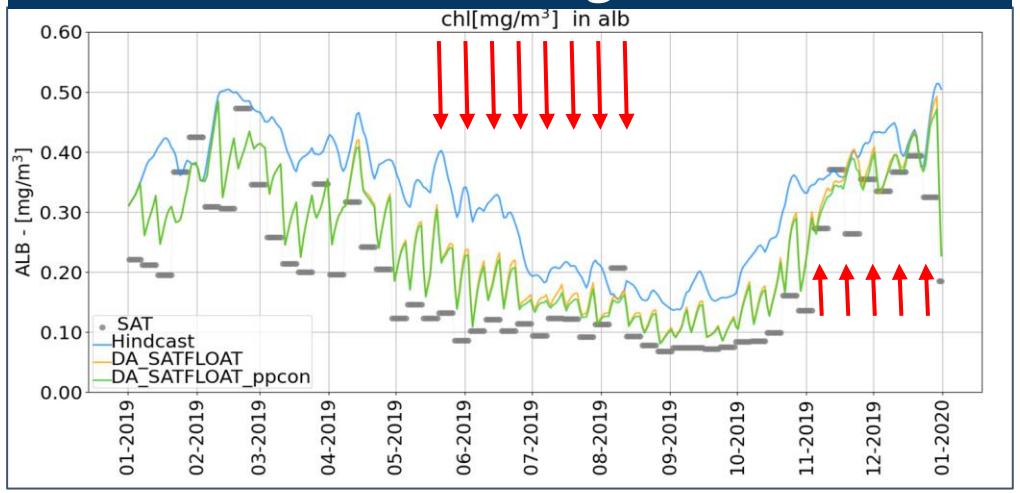
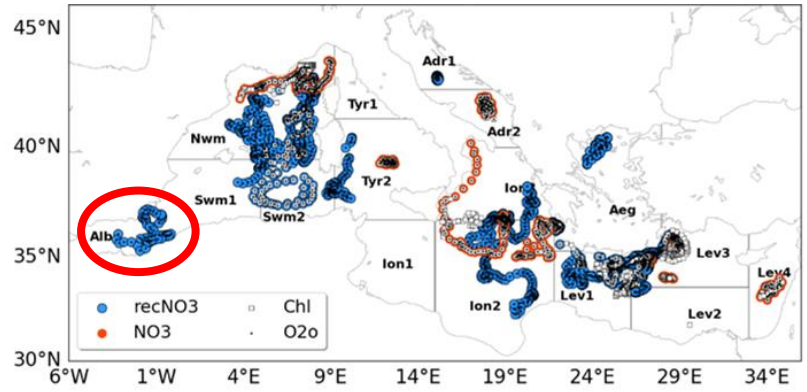


Alb [chla] mg m-3





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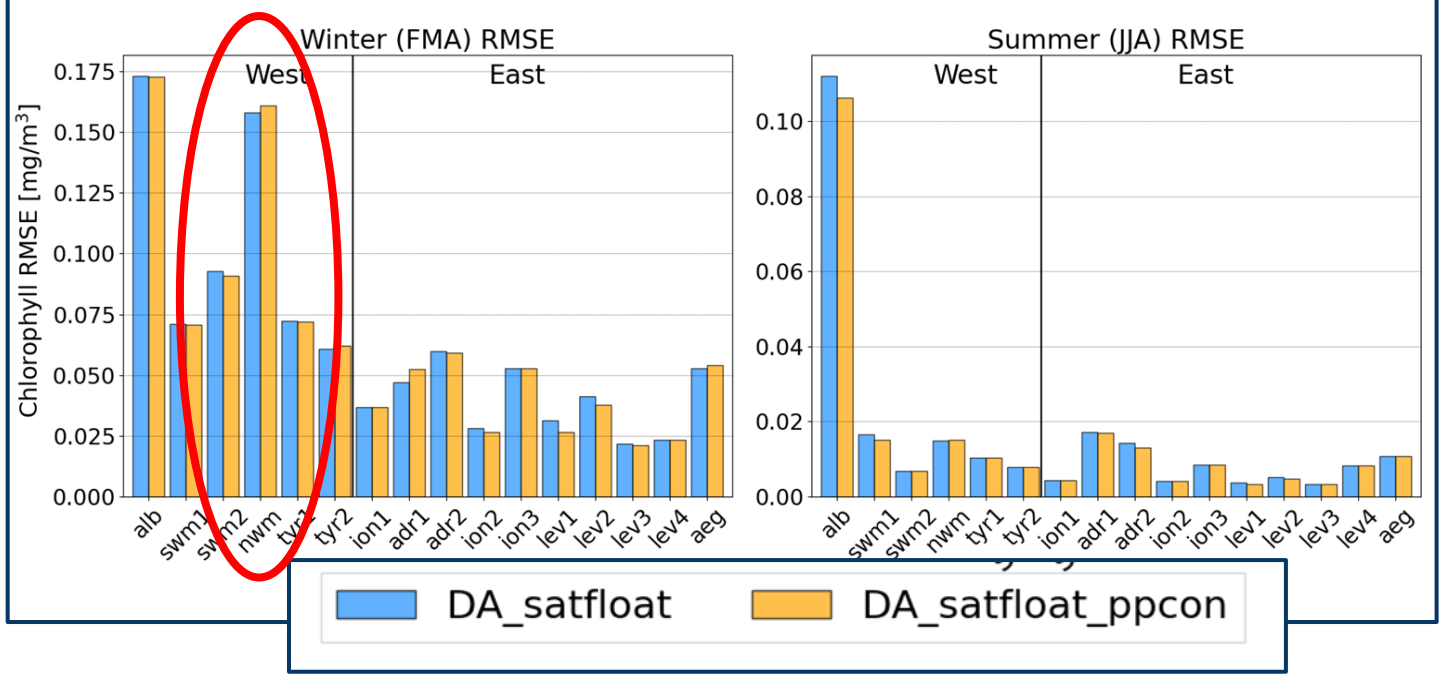
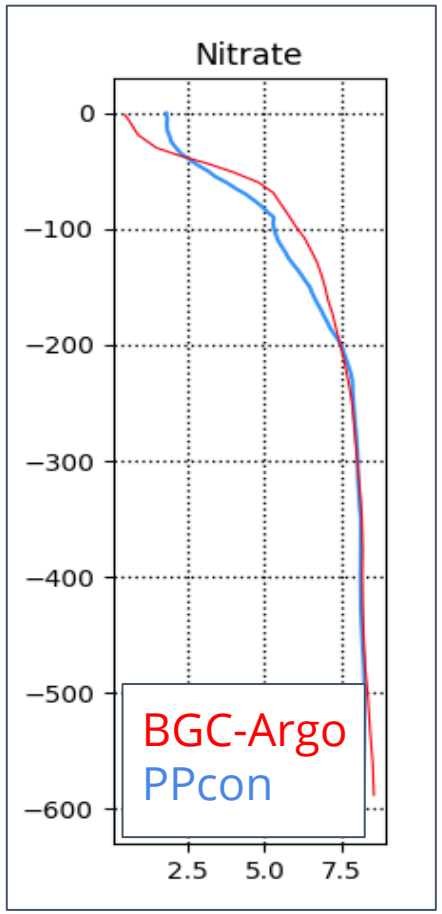
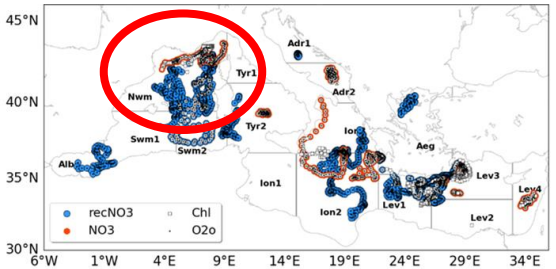
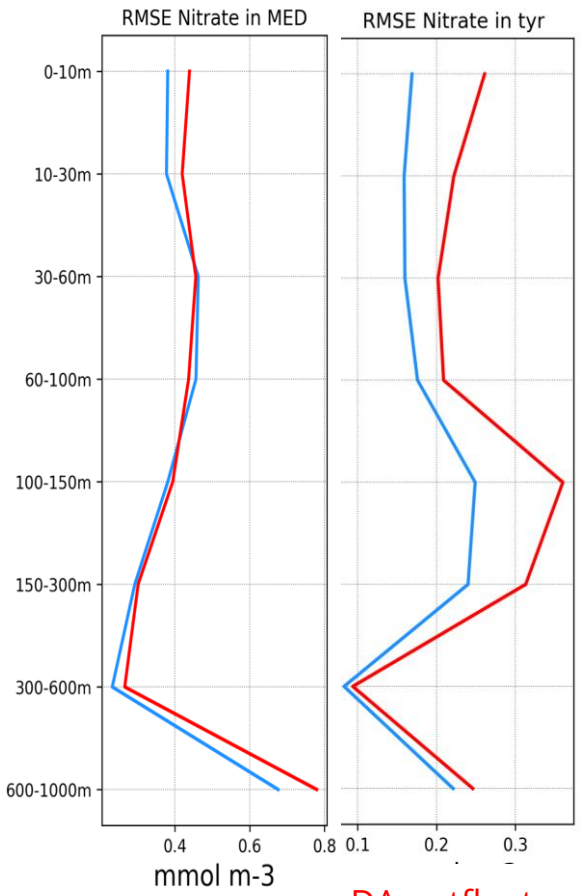






Results: OSE validation (BGC-Argo dataset)

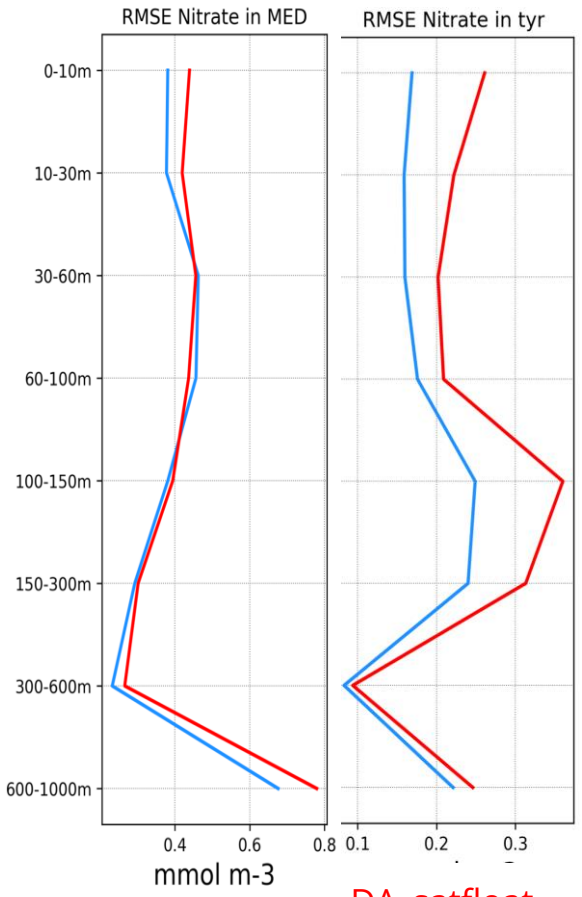


DA_satfloat
DA_satfloat_ppcon

Adding PPCon data positively impacts on:

1. **Nutrients dynamics at large scale (Med)**
2. **Nutrients dynamics at sub-basin scale (tyr)**
3. The reproduction of Chla-blooms (mixed conditions) and DCM during stratification (DCM 85m and 77m).

Results: OSE validation (BGC-Argo dataset)



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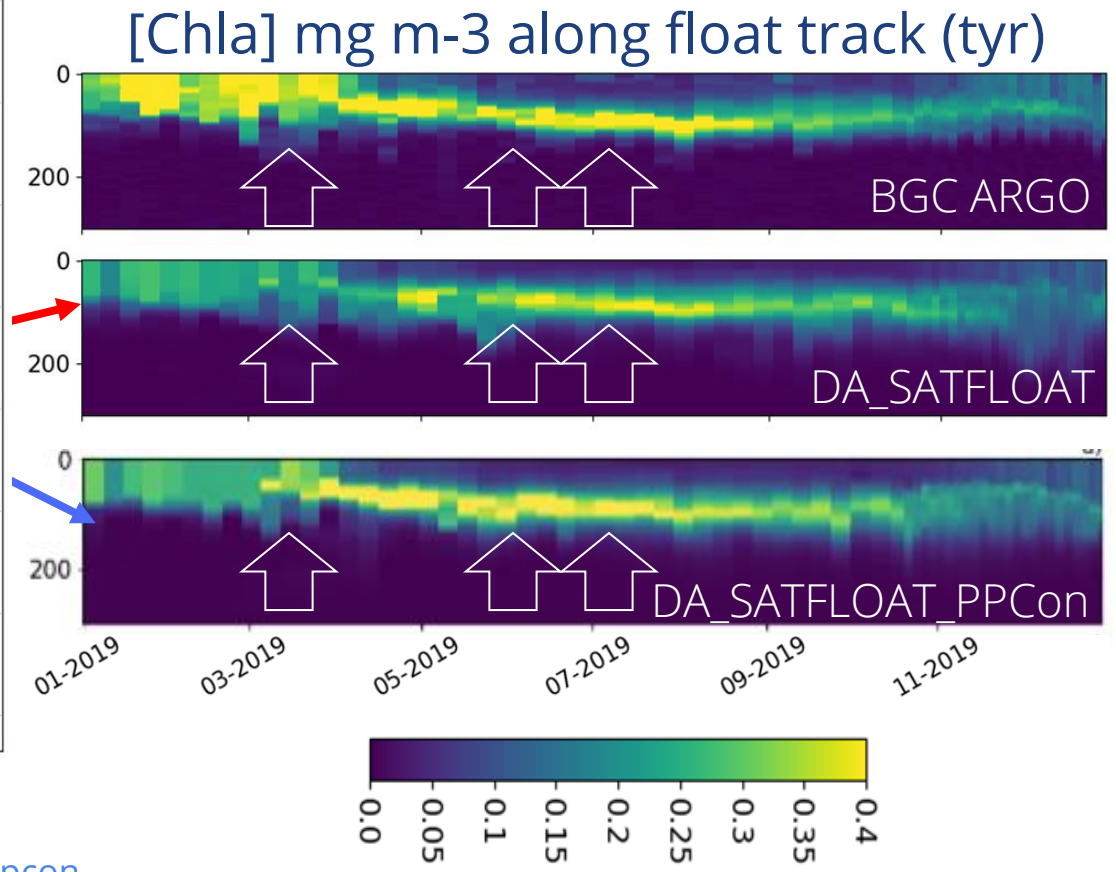

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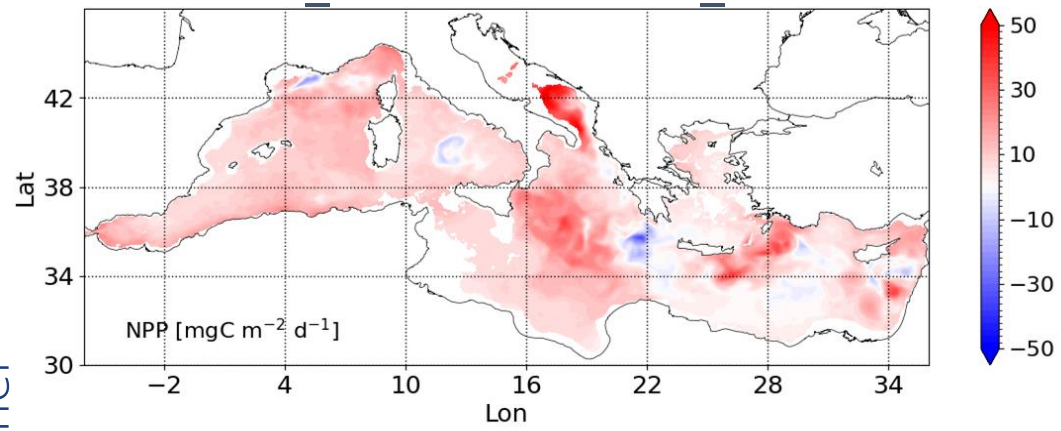
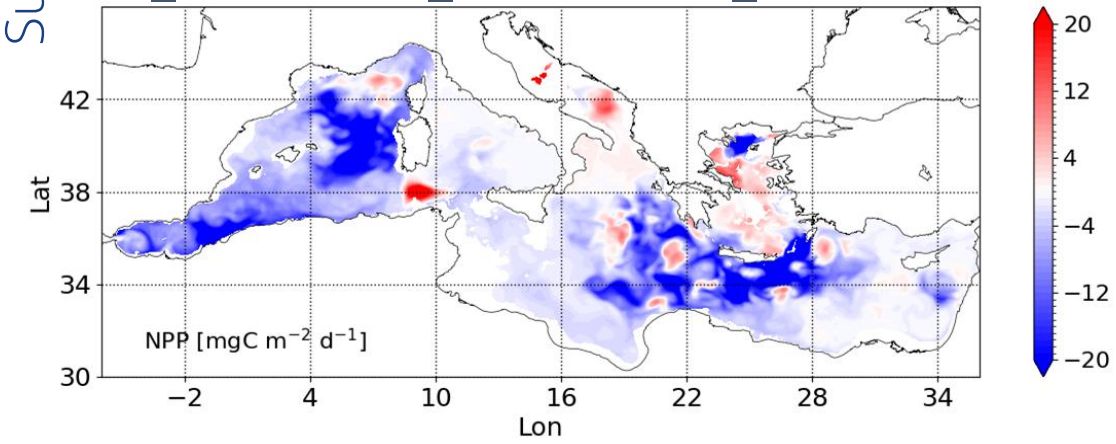
Results: PPCon impact on independent variable (Net Primary Production)

Summer

DA_SATFLOAT - DA_SAT

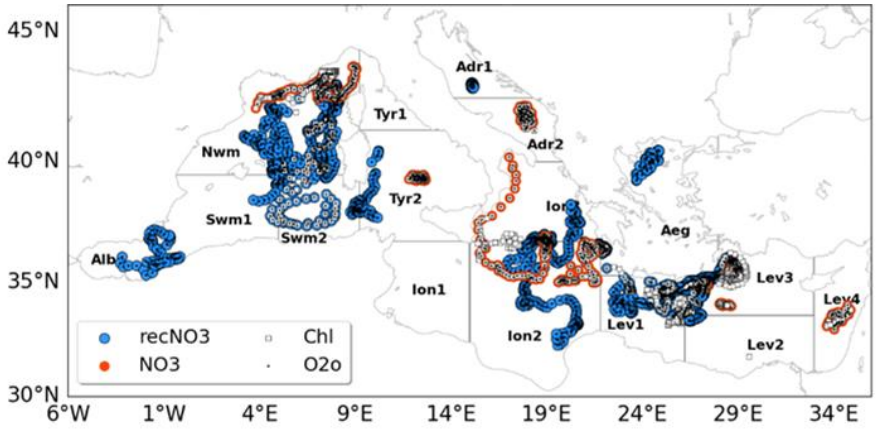


DA_SATFLOAT_PPCon - DA_SATFLOAT



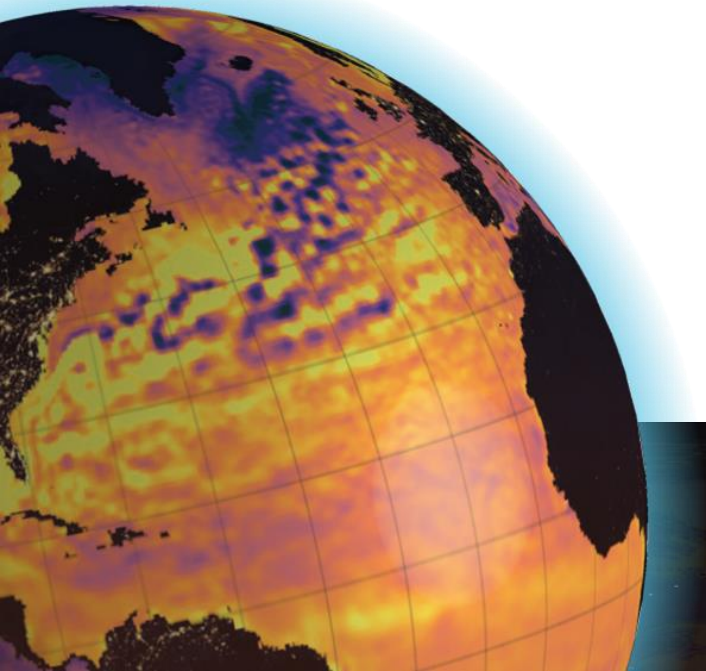
Integrated Net Primary Production 0-200 m

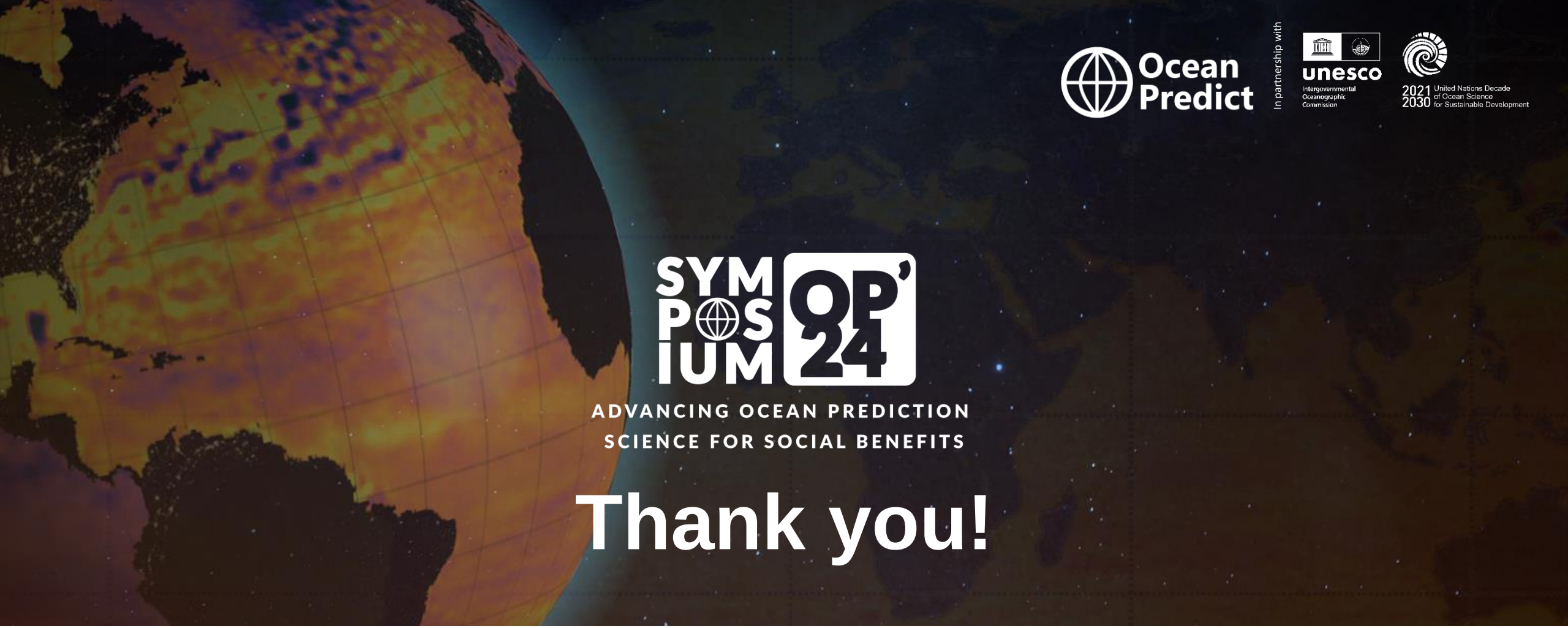
- Mean Summer NPP ~600 mgC m-2d-1
- Adding in situ data (BGC-ARGO), NPP increases
- Adding PPCon data, NPP shows high spatial variability



Summarizing:

- Predicting PPCon profiles allows to deal with reduction of available observation
- PPCon profiles has **positive effects on phytoplankton** dynamic (satellite validation)
- PPCon profiles **improve nutrient dynamics** at different time-space scales (BGC-ARGO validation) impacting chlorophyll dynamic (along track)
- The DA PPCon **has a bottom-up control** on net primary production (by correcting fertilization)





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