Project overview

Project coordinator: Stefano Ciavatta, Plymouth Marina Laboratory

Project manager, Jessica Heard, Plymouth Marina Laboratory

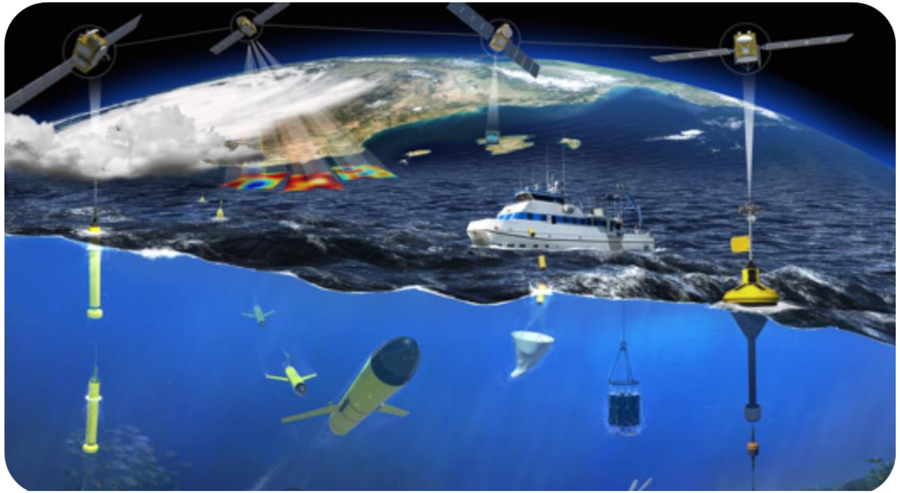
MEAP-TT meeting, 10th March 2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776480

@SEAMLESSproject
www.SEAMLESSproject.org

Vision and mission

Novel opportunities and aspiration
to predict better ocean ecosystems,
by integrating new data and models



Vision
to support sustainable food-security
from the ocean in a changing climate

Mission
to improve the operational simulation
of indicators related to
climate impact, marine food-webs and
stakeholders' needs

A predicted ocean

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

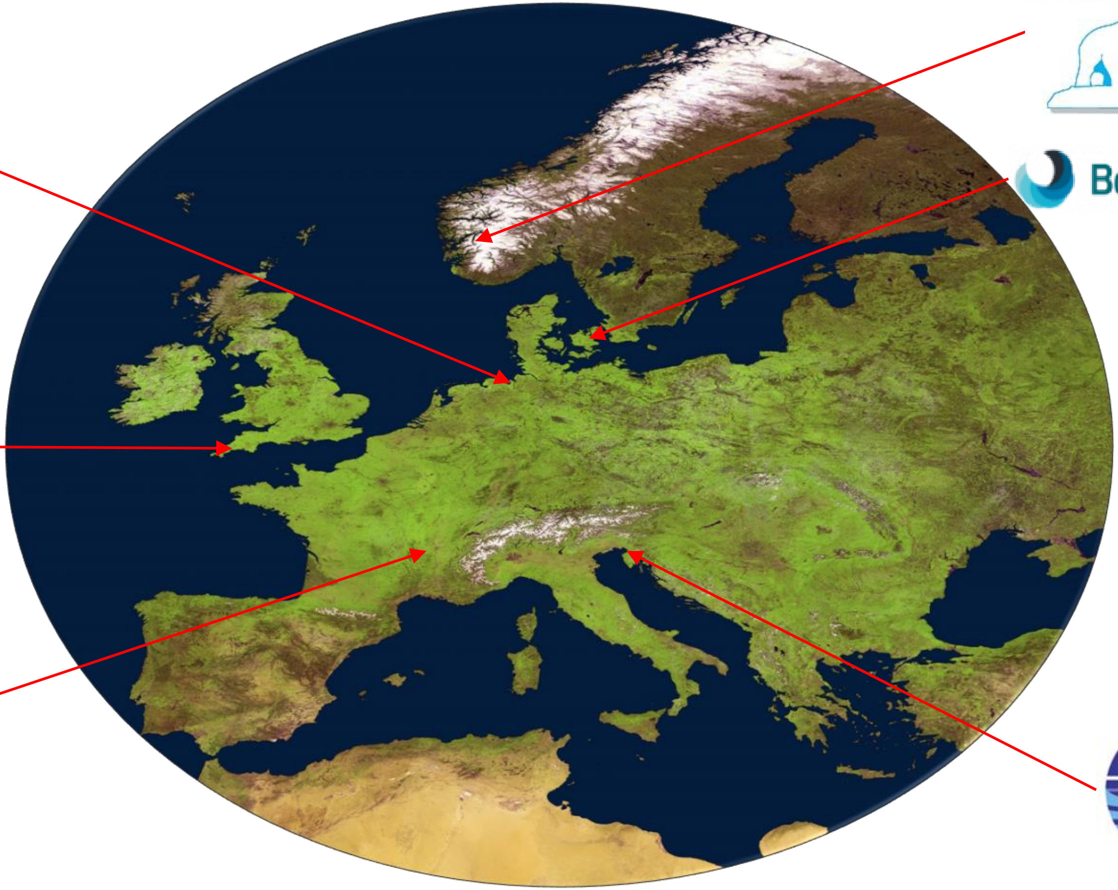
Partners

NERSC

AWI

Bolding & Bruggeman

PML | Plymouth Marine Laboratory



Budget:
Euro 1.5M

UGA
Université Grenoble Alpes

cnrs

OGS

Stakeholders

European Commission

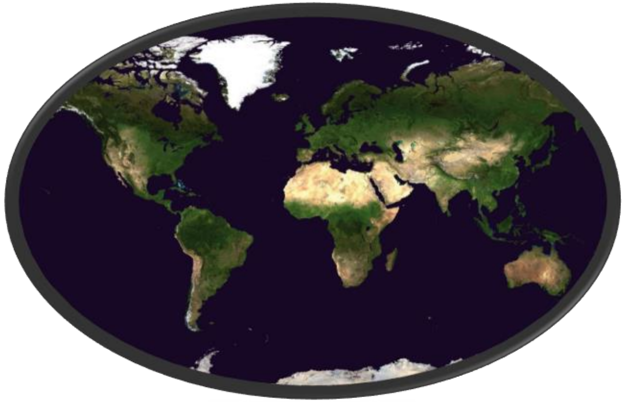
Copernicus Marine Service

ISPRA
Italian National Institute for Environmental Protection and Research

esa

OceanPredict
Advancing the science of ocean prediction

UNIVERSITAS BERGENSIS



INSTITUTE OF MARINE RESEARCH

biogeochemical Argo

The Danish Meteorological Institute

MBARI
Monterey Bay Aquarium Research Institute

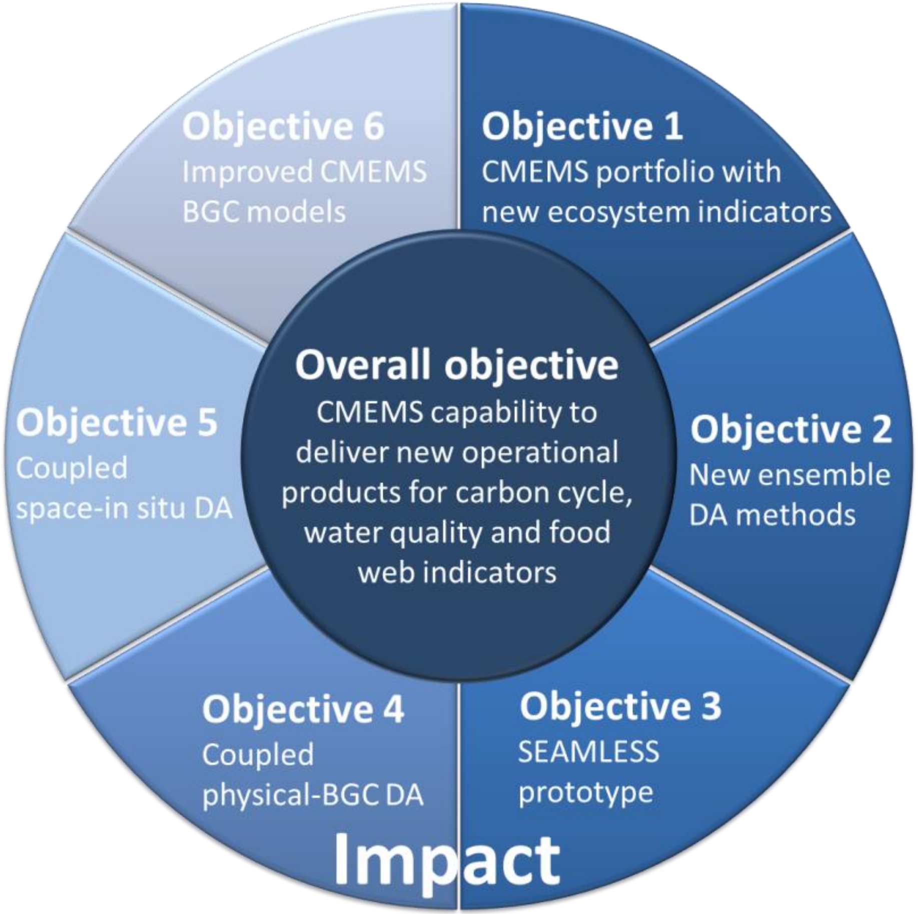
IOCCG
International Ocean Colour Coordinating Group

HORIZON 2020

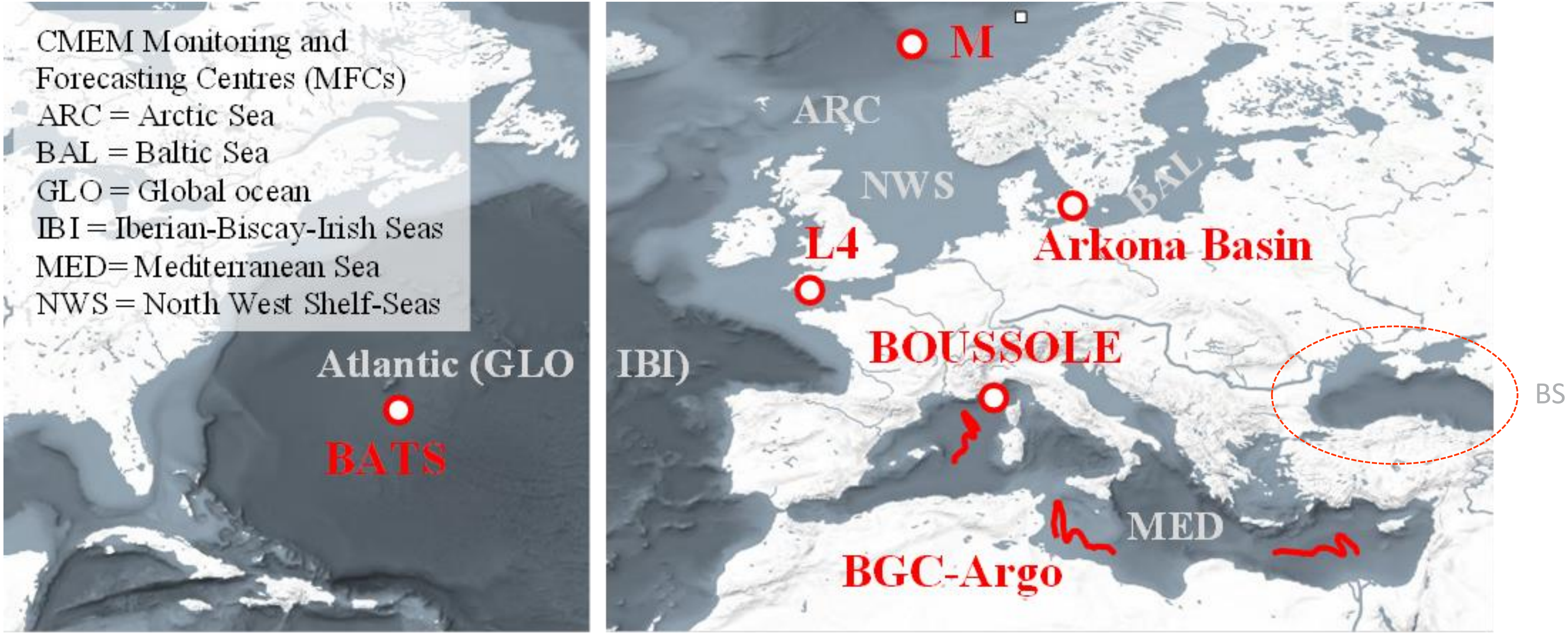
immerse
IMPROVING OCEAN MODELS FOR THE COPERNICUS PROGRAMME

COMFORT
Our common future ocean in the Earth system

Objectives


Objective 6
Improved CMEMS BGC models
Objective 1
CMEMS portfolio with new ecosystem indicators
Overall objective
CMEMS capability to deliver new operational products for carbon cycle, water quality and food web indicators
Objective 5
Coupled space-in situ DA
Objective 2
New ensemble DA methods
Objective 4
Coupled physical-BGC DA
Objective 3
SEAMLESS prototype
Impact

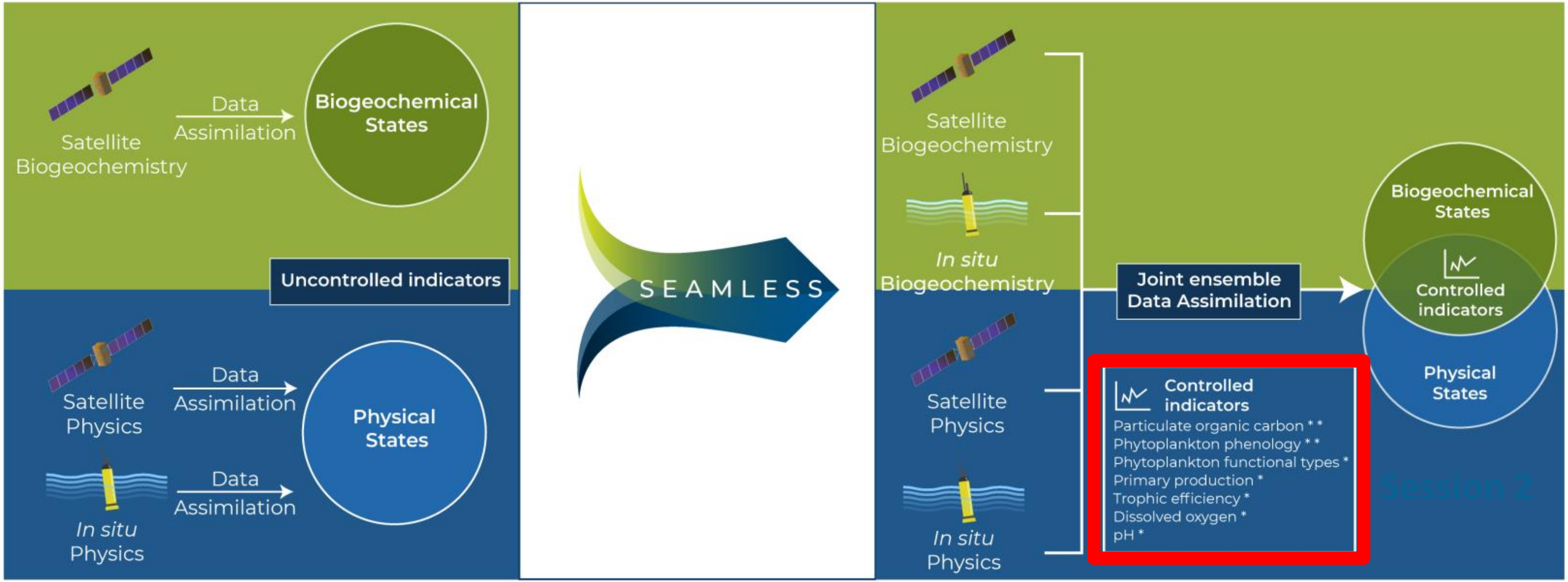
SEAMLESS links to CMEMS MFCs



BGC models: PISCES, ERSEM, BFM, ECOSMO, ERGOM, [BAHMBI]
Physical models: NEMO, HYCOM, HBM

Science overview

CMEMS current approach | The SEAMLESS prototype



Hypothesis: New integrated observing networks and advanced ensemble data assimilation methods can improve the simulation of marine ecosystem indicators (i.e. increase their observability, controllability and identifiability)

The four research streams

1. New ensemble generation and data assimilation methods

to maximize the flow of information from the new observing networks towards the controllable ecosystem indicators

2. Coupled assimilation of physical and biogeochemical data,

to improve the consistency of the biogeochemical and physical simulations

3. Coupled assimilation of remote sensing and in situ biogeochemical data

to link the surface and subsurface ecosystem dynamics

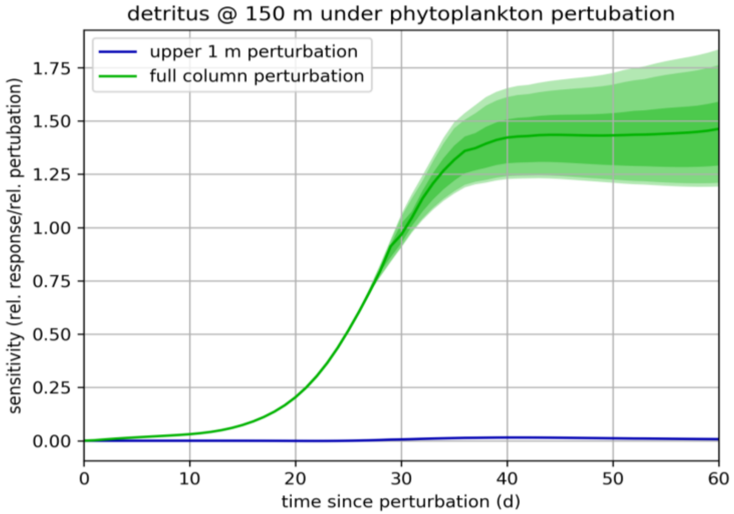
4. Coupled assimilation for joint state-parameter estimation,

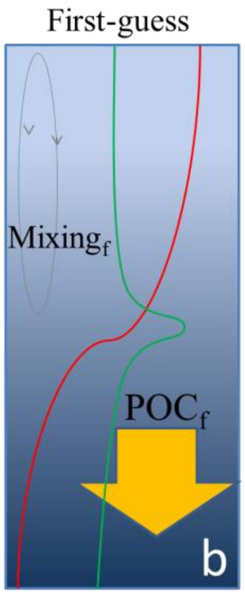
to improve the models and their simulation of biogeochemical indicators.

WP3 Scientific strategy (II)

- Develop a **strategy to focus on perturbations** that most effectively reduce the uncertainty of the **SEAMLESS target indicators** (POC, trophic efficiency, PP, pH, O2, PFT, Phenology) in the different CMEMS regions, according to the **system's observability / controllability**

- Task 3.2 - Example of GOTM-FABM-ERSEM at BATS (1D) :

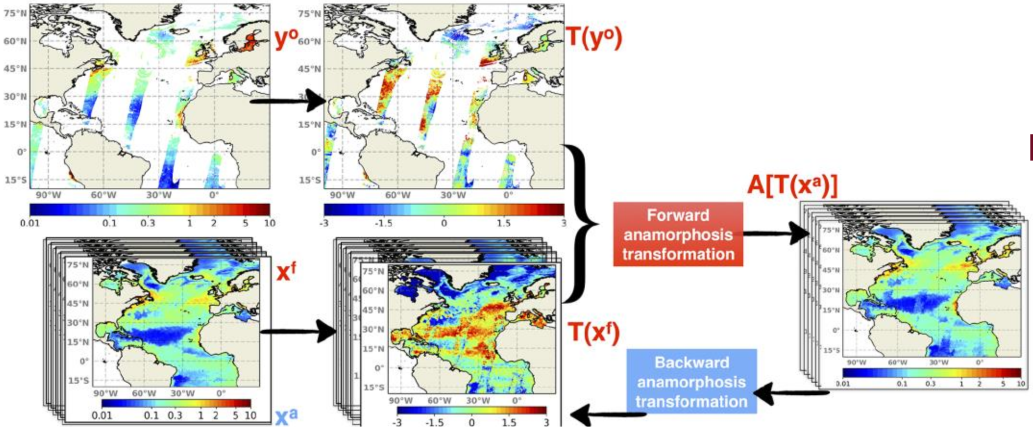




WP3 Scientific strategy (I)

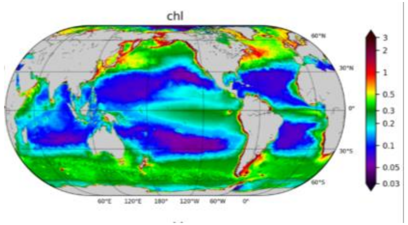
- Consolidation of **ensemble generation methods used to inject stochasticity in the coupled physical-BGC models**, e.g. through (i) initial conditions, (ii) external surface/lateral forcing, (iii) internal physical parameters (e.g. ocean mixing schemes) and biological parameters (BGC processes), (iv) intrinsic model equation solvers. **Ensemble methods can combine all perturbations together to explore their nonlinear interactions.**

- Task 3.1 - Example for NEMO/PISCES



Stochastic NEMO-PISCES (Santana-Falcon et al., 2020)

Deterministic MOI run (2014)



iORCA025 grid (75 levels)
Online coupling PHY-BGC
PHY: forçages atm ERA5, VVL, GLS...
BGC: climatology for initialization: WOA2018 + GLODAP

Up-to-date NEMO-PISCES-4

SEAMLESS transformation of the CMEMS MFCs

MFC	DA method
NWS	NEMOVar
	Hybrid Ensemble NEMOVar
IBI	None
	SEEK stochastic error parameters
GLO	SEEK (climatological base)
	SEEK stochastic error parameters
MED	3DVarBio
	Hybrid Ensemble 3DVarBio
BAL	ESTKF in preparation
	Hybrid EnKF PF
ARC	DEnKF/EnKS
	DEnKF/EnKS

The four research streams

1. New ensemble generation and data assimilation methods
to maximize the flow of information from the new observing networks towards the controllable ecosystem indicators

2. Coupled assimilation of physical and biogeochemical data,
to improve the consistency of the biogeochemical and physical simulations

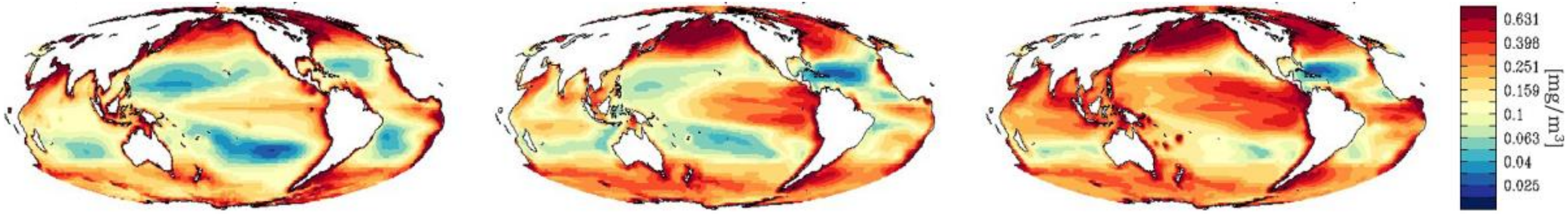
3. Coupled assimilation of remote sensing and in situ biogeochemical data
to link the surface and subsurface ecosystem dynamics

4. Coupled assimilation for joint state-parameter estimation,
to improve the models and their simulation of biogeochemical indicators.

Coupled physical and biogeochemical data assimilation (BGC helps PHY)

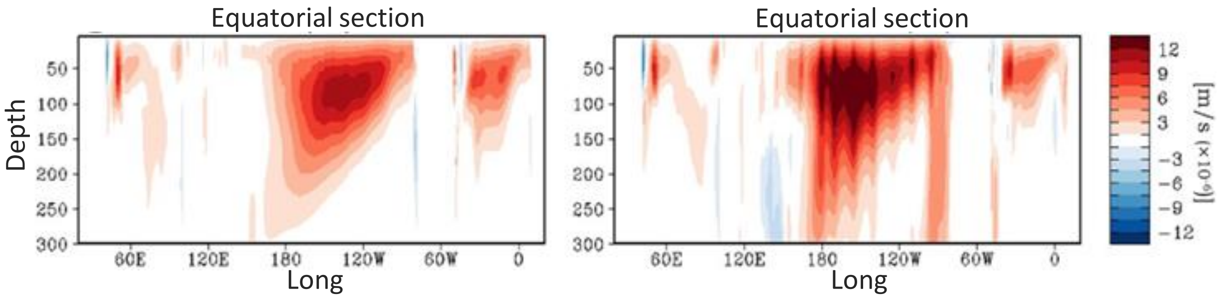
Data | Control | PHY-DA

Chlorophyll

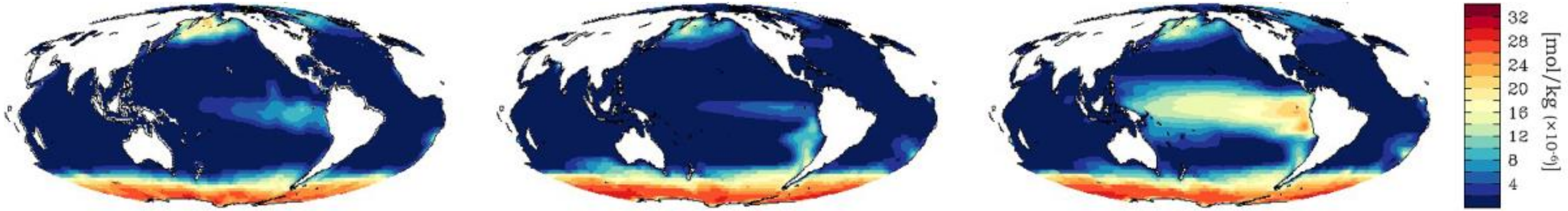


Vertical velocity

…is deteriorated*



Nitrate

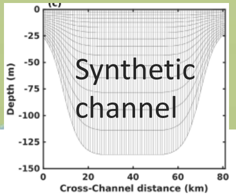


- "Incremental pressure corrections" (Waters et al., 2017)
- "Pragmatic fixes" (Park et al., 2018)

…did not really fix the issue

Park et al., 2018

Coupled physical and biogeochemical data assimilation (BGC helps PHY)

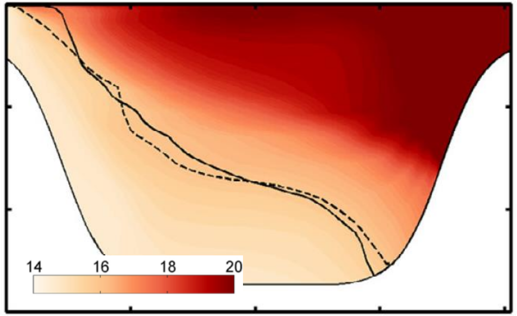


Temperature (°C)

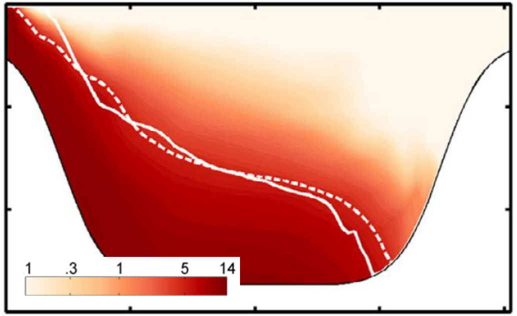
Nitrate (mmol m^{-3})

Control

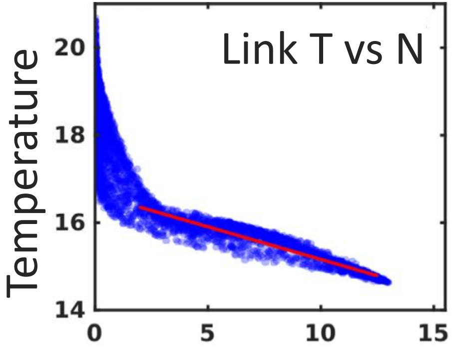
Depth (m)



Width (km)



Width (km)

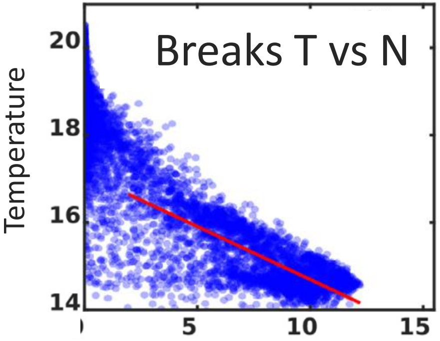


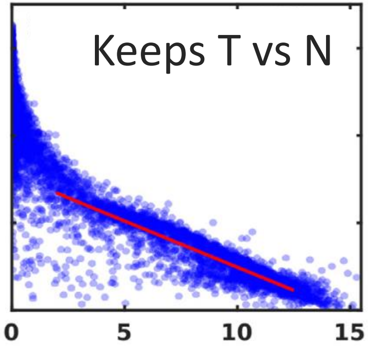
DA PHY to correct PHY

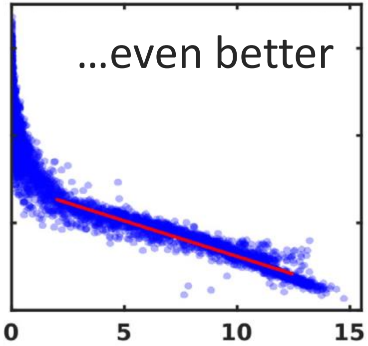
DA PHY to correct PHY & BGC

DA BGC to correct PHY & BGC

DA trials







Yu et al., 2018

The four research streams

1. New ensemble generation and data assimilation methods
to maximize the flow of information from the new observing networks towards the controllable ecosystem indicators

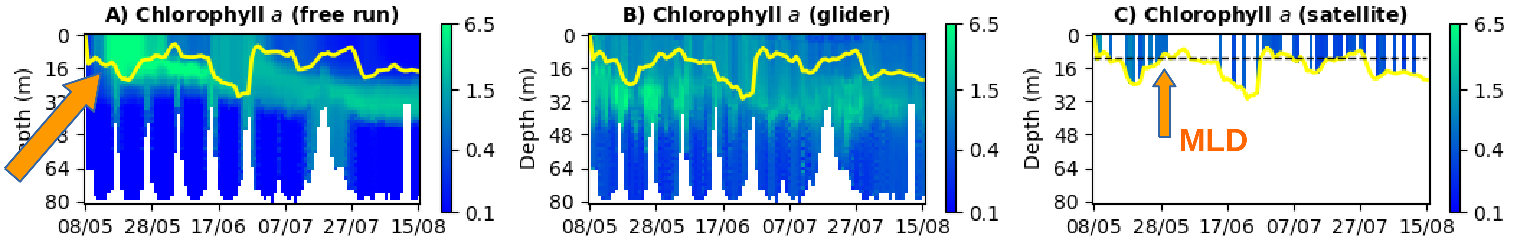
2. Coupled assimilation of physical and biogeochemical data,
to improve the consistency of the biogeochemical and physical simulations

3. Coupled assimilation of remote sensing and in situ biogeochemical data
to link the surface and subsurface ecosystem dynamics

4. Coupled assimilation for joint state-parameter estimation,
to improve the models and their simulation of biogeochemical indicators.

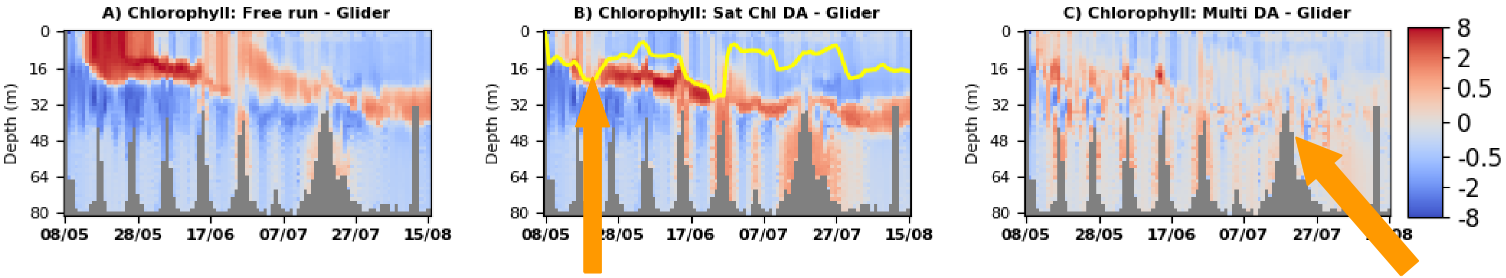
Assimilation of satellite SST and OC + glider physical (T,S) and BGC (chl, O2) on the NWE Shelf (NEMO-FABM-ERSEM) – PML

- The multi-platform (satellite-glider) assimilation optimally combines all the benefits of single platform systems and substantially improves the simulation of all the assimilated variables



The model free run shows late spring bloom (chlorophyll)

Difference between analysis and observations



The satellite OC assimilation corrects chlorophyll within ML, whilst multi-platform assimilation across the whole water column

The four research streams

1. New ensemble generation and data assimilation methods
to maximize the flow of information from the new observing networks towards the controllable ecosystem indicators

2. Coupled assimilation of physical and biogeochemical data,
to improve the consistency of the biogeochemical and physical simulations

3. Coupled assimilation of remote sensing and in situ biogeochemical data
to link the surface and subsurface ecosystem dynamics

4. Coupled assimilation for joint state-parameter estimation,
to improve the models and their simulation of biogeochemical indicators.

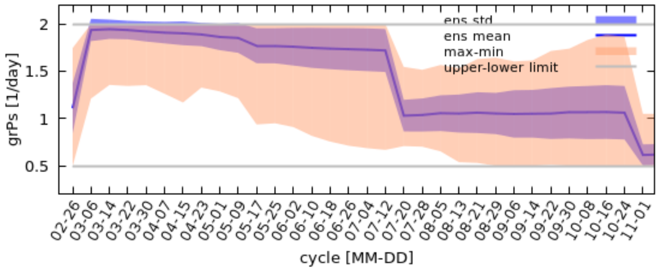
BGC model global parameter estimation

Seasonal adjustment in the estimated BGC model parameters observed

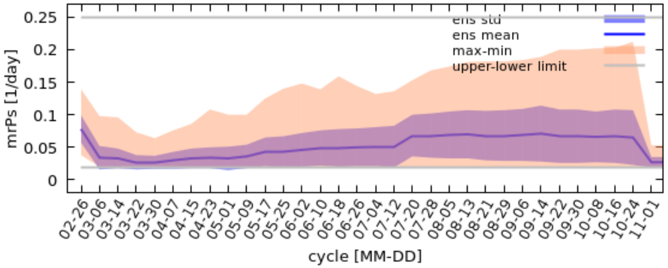
parameter [unit]	grPl [1/day]	grPs [1/day]	mrPl [1/day]	mrPs [1/day]	mrZ|l [1/day]	mrZ|s [1/day]	srDO [m/day]	CrSi [molC/molSi]
error [%]	20	20	20	20	20	20	20	20
Min	0.8	0.5	0.02	0.02	0.05	0.05	3.5	3.0
Max	3.0	2.0	0.25	0.25	0.4	0.4	20.0	13.0
initial estimate	1.27	1.099	0.039	0.079	0.097	0.199	5.049	6.752
Reanalysis estimate	2.432	1.728	0.047	0.051	0.098	0.190	4.723	6.956

grPl: growth rate of large phytoplankton. grPs: growth rate of small phytoplankton. mrPl: mortality rate of large phytoplankton. mrPs: mortality rate of small phytoplankton. mrZl: mortality rate of large zooplankton. mrZs: mortality rate of small zooplankton. srDO: sinking rate of detritus and opal. CrSi: Carbon to Silicate ratio. Reanalysis estimated values are from 04/07/2007.

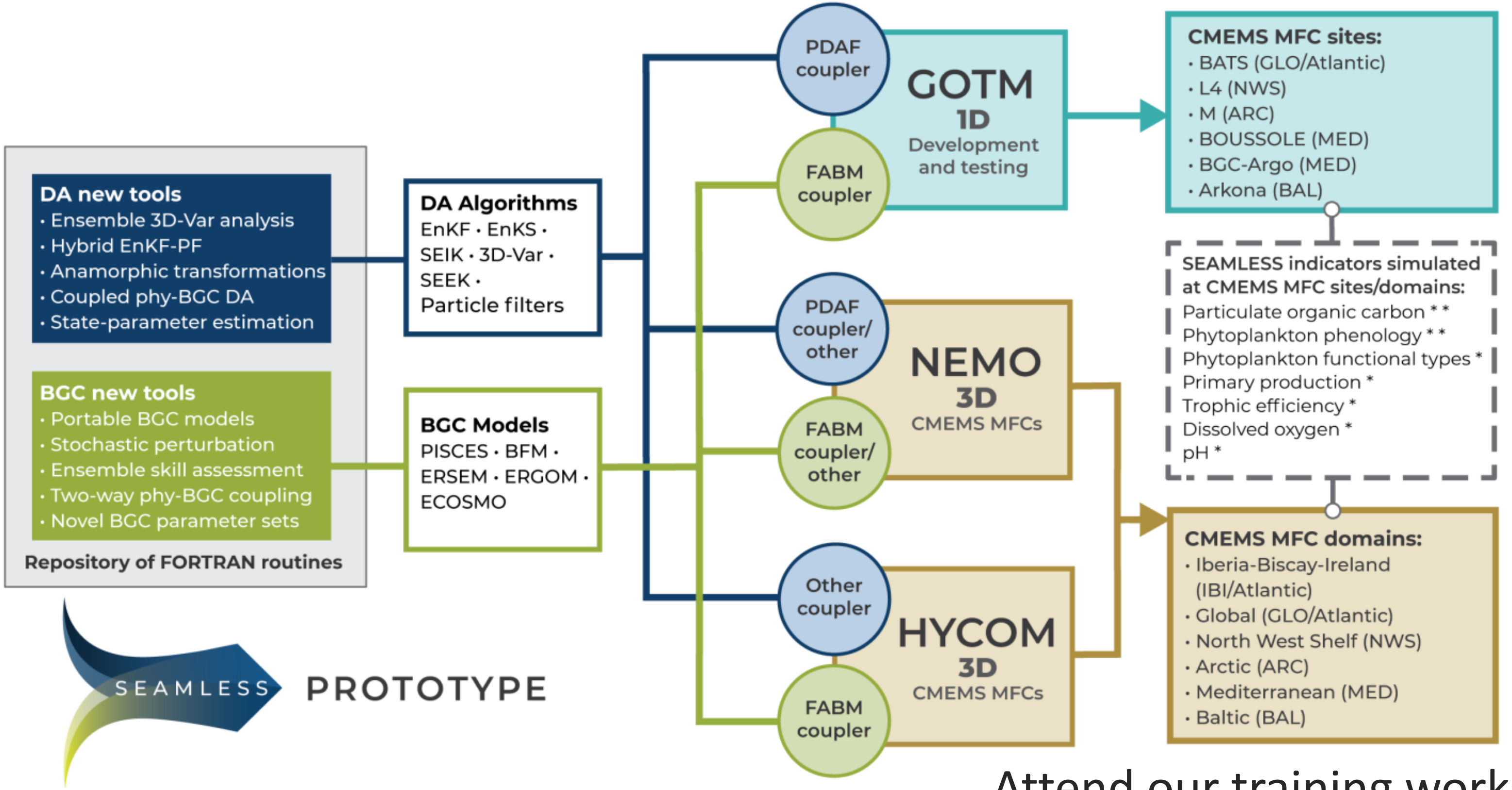
grPs



mrPs



The SEAMLESS prototype



Attend our training workshops!

SEAMLESS transformation of the CMEMS MFCs

MFC	DA method	Assimilated BGC data	PHY-BGC coupled DA	SAT-IS coupled DA	Improved parameters
NWS	NEMOVar	OC: PFT chl	No	No	NA
	Hybrid Ensemble NEMOVar	OC: chl, ops IS: chl [g], N [g], P [g]	Yes	Yes	Yes
IBI	None	No	No	No	NA
	SEEK stochastic error parameters	OC: chl	Yes	No	Yes
GLO	SEEK (climatological base)	OC: chl	No	No	NA
	SEEK stochastic error parameters	OC: chl	Yes	No	Yes
MED	3DVarBio	OC: chl	No	No	NA
	Hybrid Ensemble 3DVarBio	OC: chl IS:chl [a,g], N [a,g], opt [a]	No*	Yes	Yes
BAL	ESTKF in preparation	No	No	No	NA
	Hybrid EnKF PF	OC: chl	Yes	No	Yes
ARC	DEnKF/EnKS	OC: chl IS: N [b], P [b], S [b]	Yes	Yes	NA
	DEnKF/EnKS	OC: chl IS: chl [a], N [a],P [b], S [b]	Yes	Yes	Yes

Expected impacts: improve CMEMS

Copernicus Marine Service

+

Controlled indicators

Particulate organic carbon * *
Phytoplankton phenology * *
Phytoplankton functional types *
Primary production *
Trophic efficiency *
Dissolved oxygen *
pH *

SUSTAINABLE DEVELOPMENT GOALS

13 CLIMATE ACTION

14 LIFE BELOW WATER

WATER QUALITY

MARINE FOOD

SCIENCE & CLIMATE

MARINE CONSERVATION & POLICIES

"The stakeholders of our CMEMS stakeholder, are SEAMLESS stakeholders"