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How to monitor the Ocean?

Marilaure Grégoire

University of Liège, Belgium

Marilaure Grégoire, Gianpiero Cossarini, Elodie Gutknecht, Susan Kay, Julien Lamouroux, Helen Morrison, Coralie Perruche, Annette Samuelsen, Lena Spruch, Anna Teruzzi, Luc Vandenbulcke, Tsuyoshi Wakamatsu

Marine Environment Reanalyses : Biogeochemistry

- Observing the green ocean
- Modelling the green ocean
- Reanalysis products and connexion with the biology

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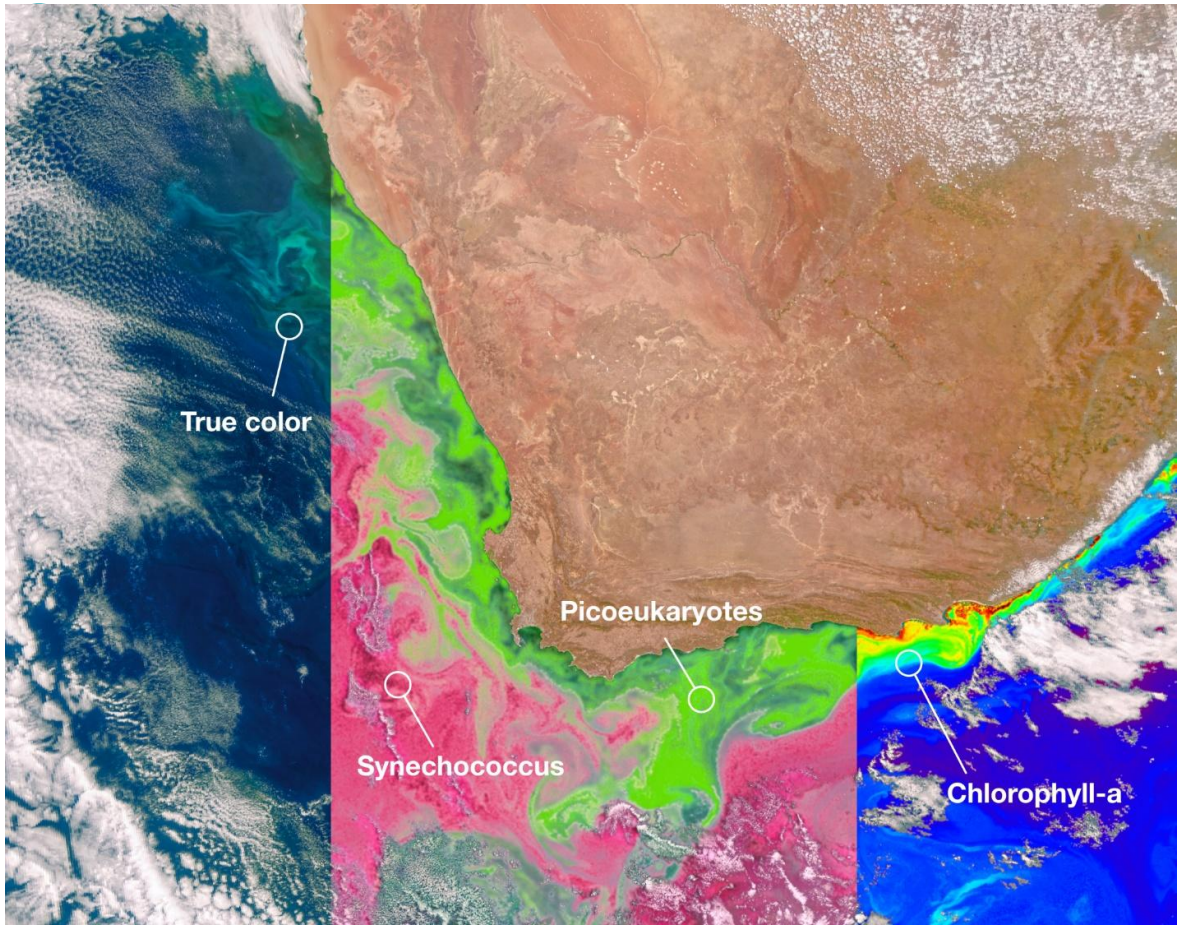
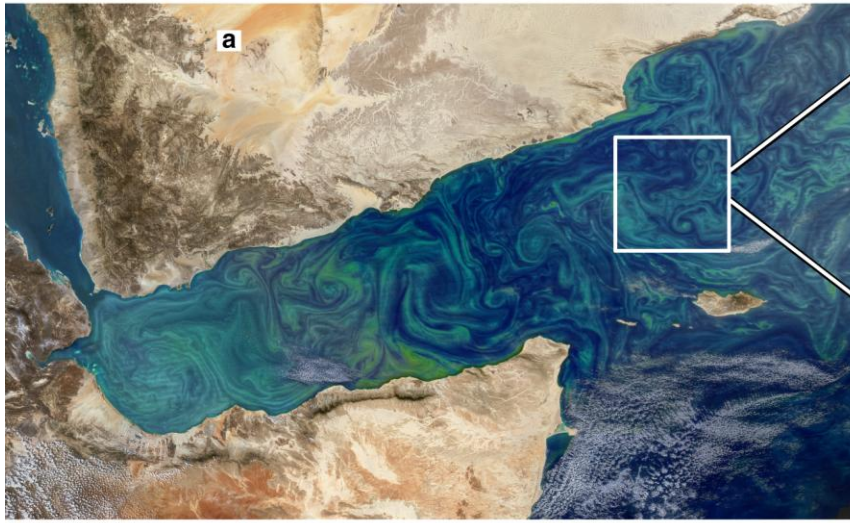
SATELLITE OBSERVATION

- Higher resolution in space, time, spectral
- Hyperspectral data offer a better connection to biology





National Aeronautics and Space Administration

Credit: Nasa

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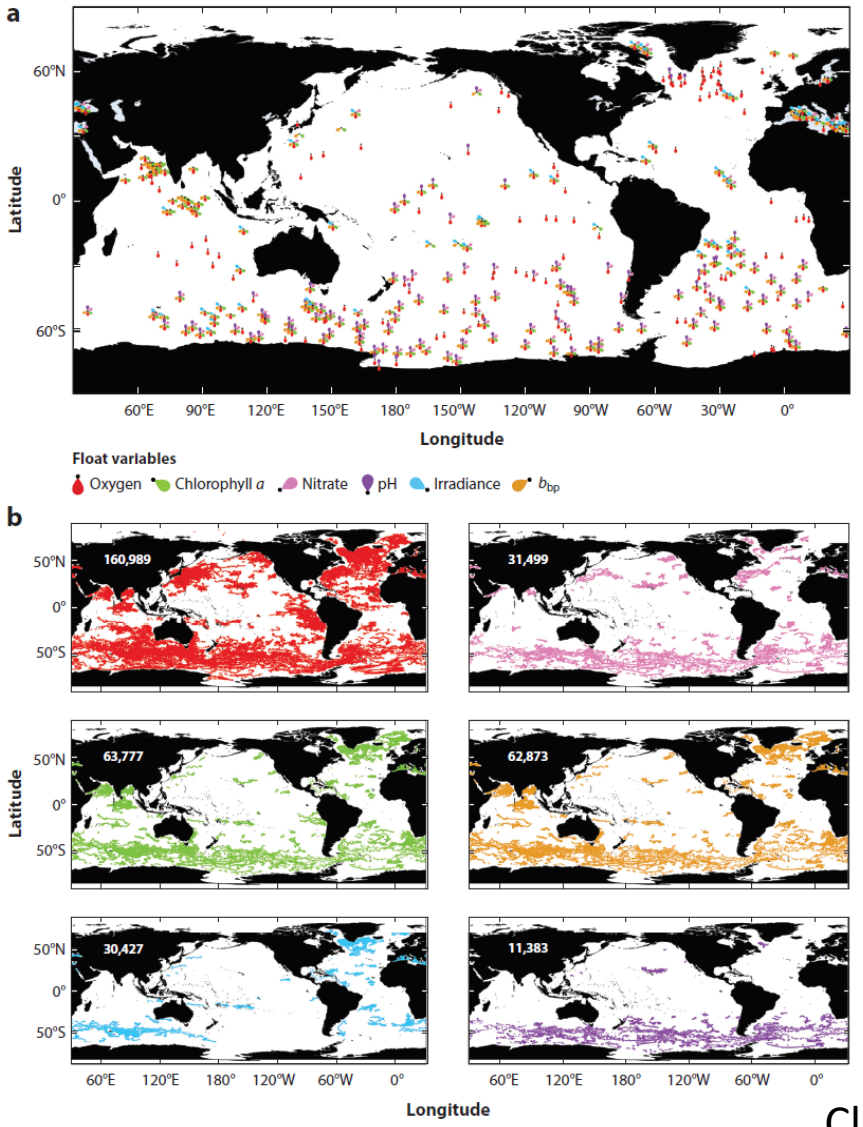
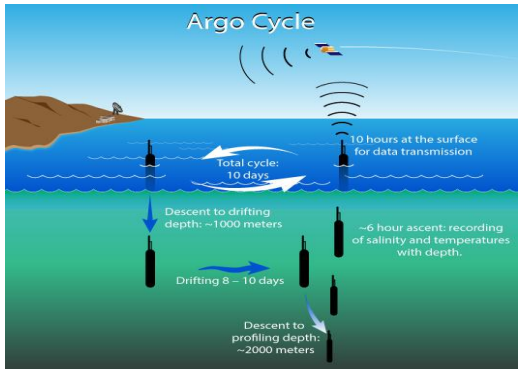
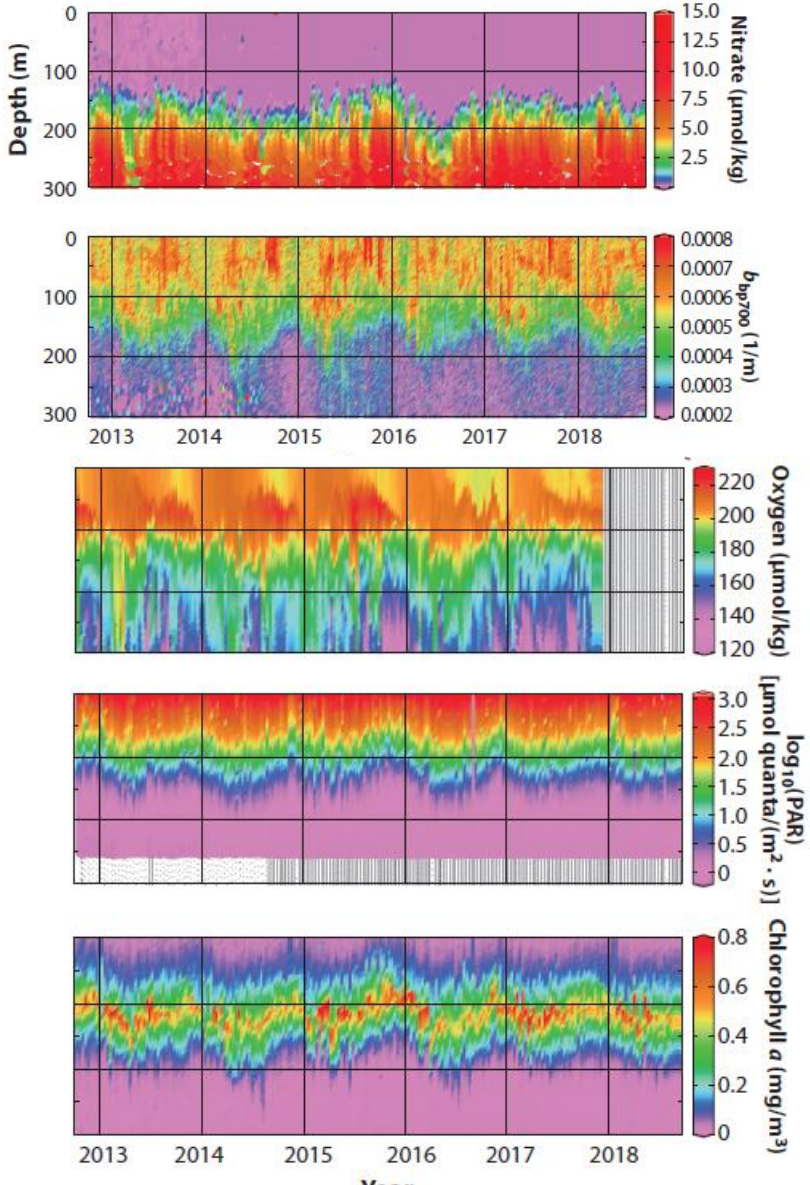
BIOGEOCHEMICAL ARGO





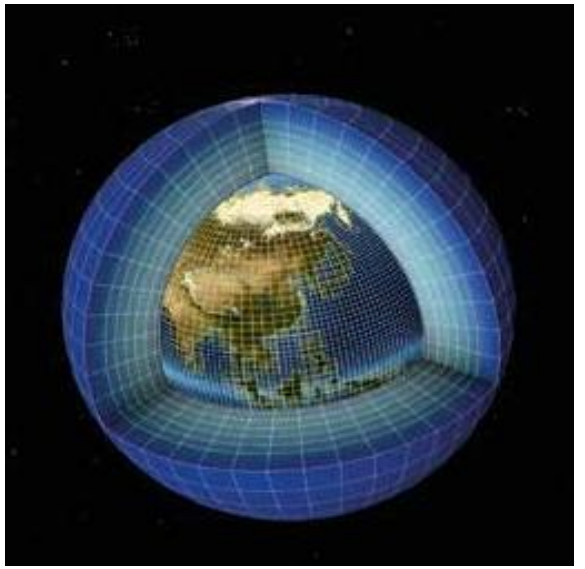
Target: 1000 BGC floats



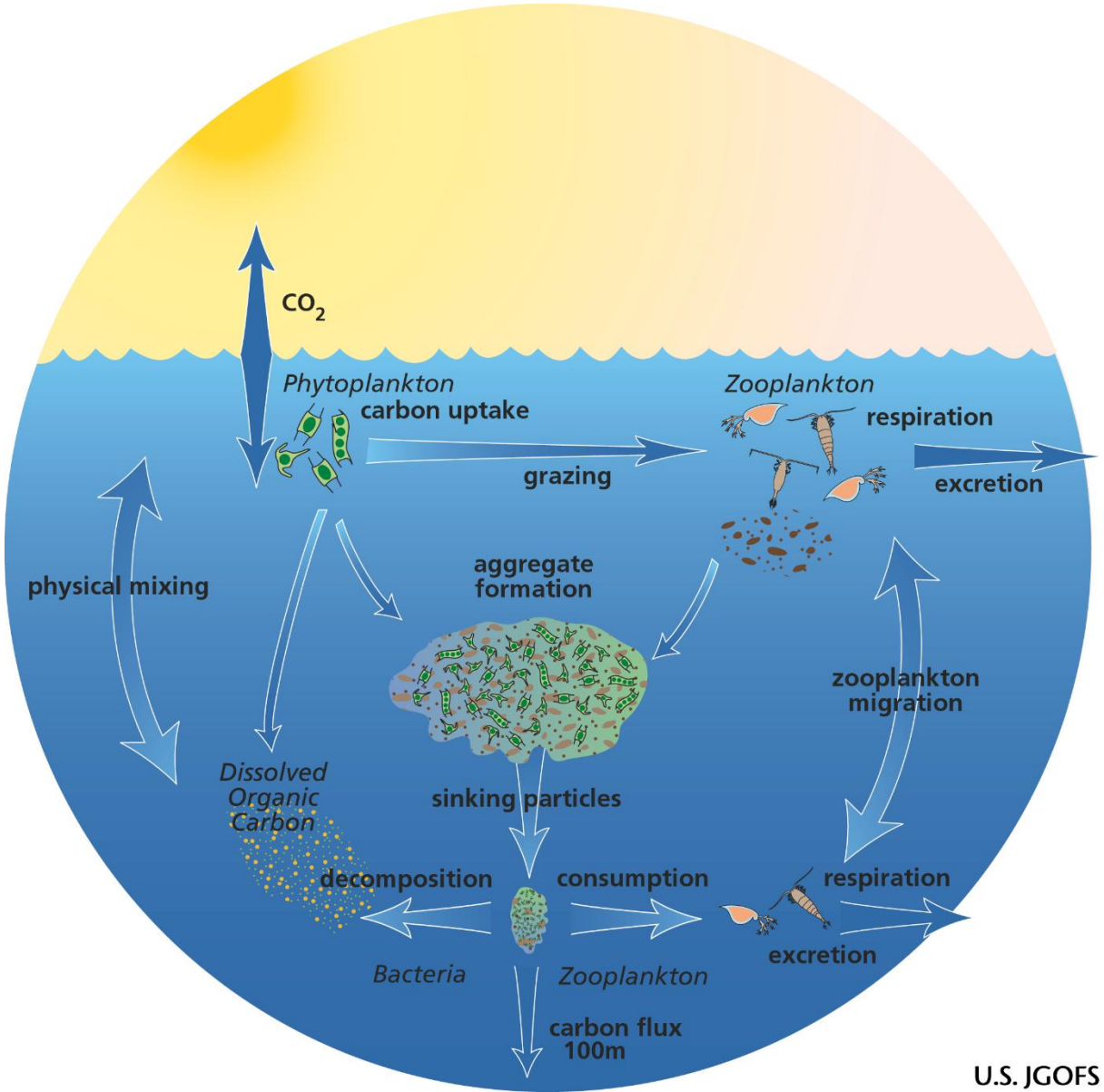
Claustre et al., 2019

NUMERICAL OCEAN

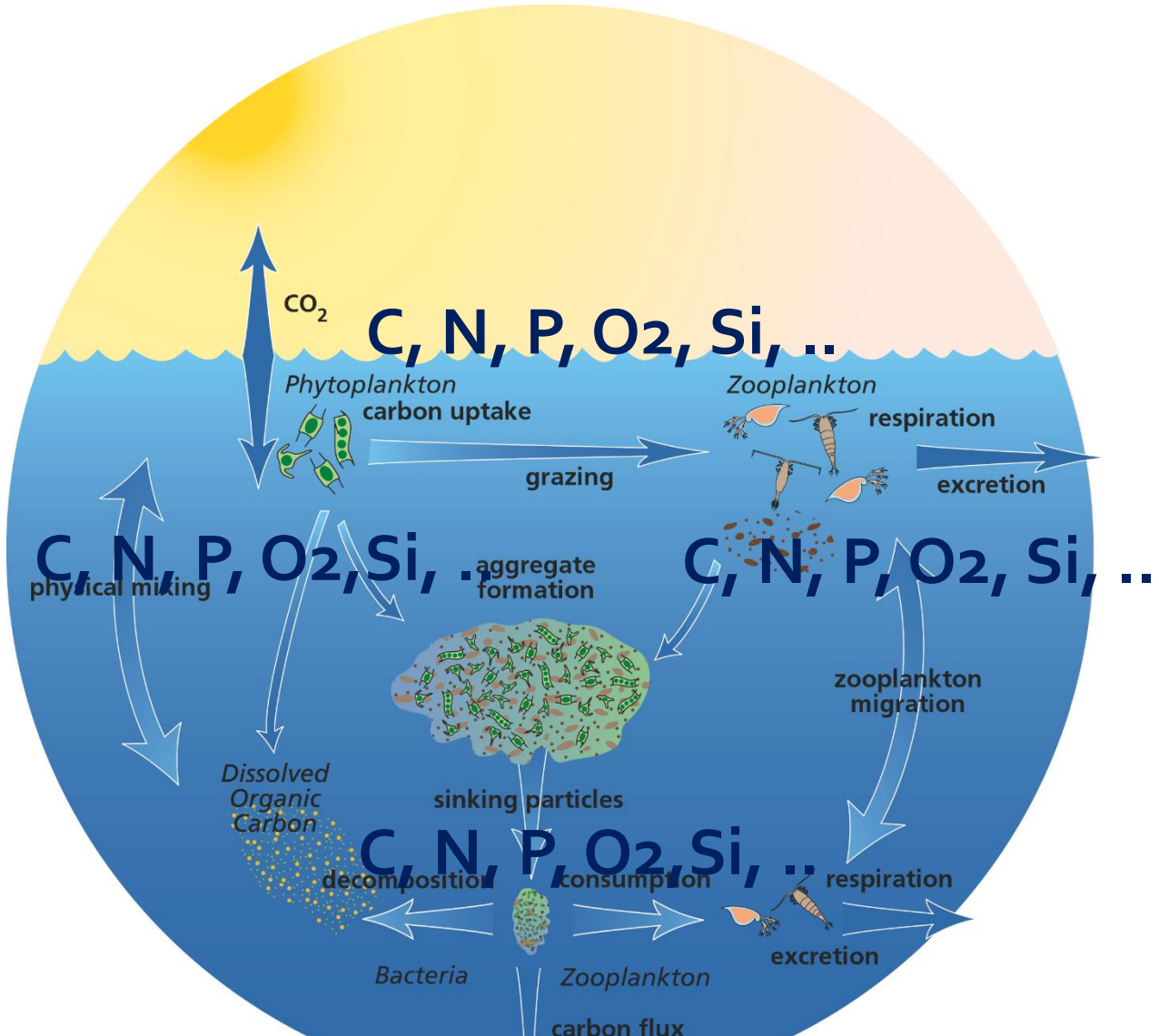
- Mass balance equations
- No equivalent to Navier-Stokes equations for biogeochemistry
- Empirical representation of biogeochemical processes based on laboratory experiments.



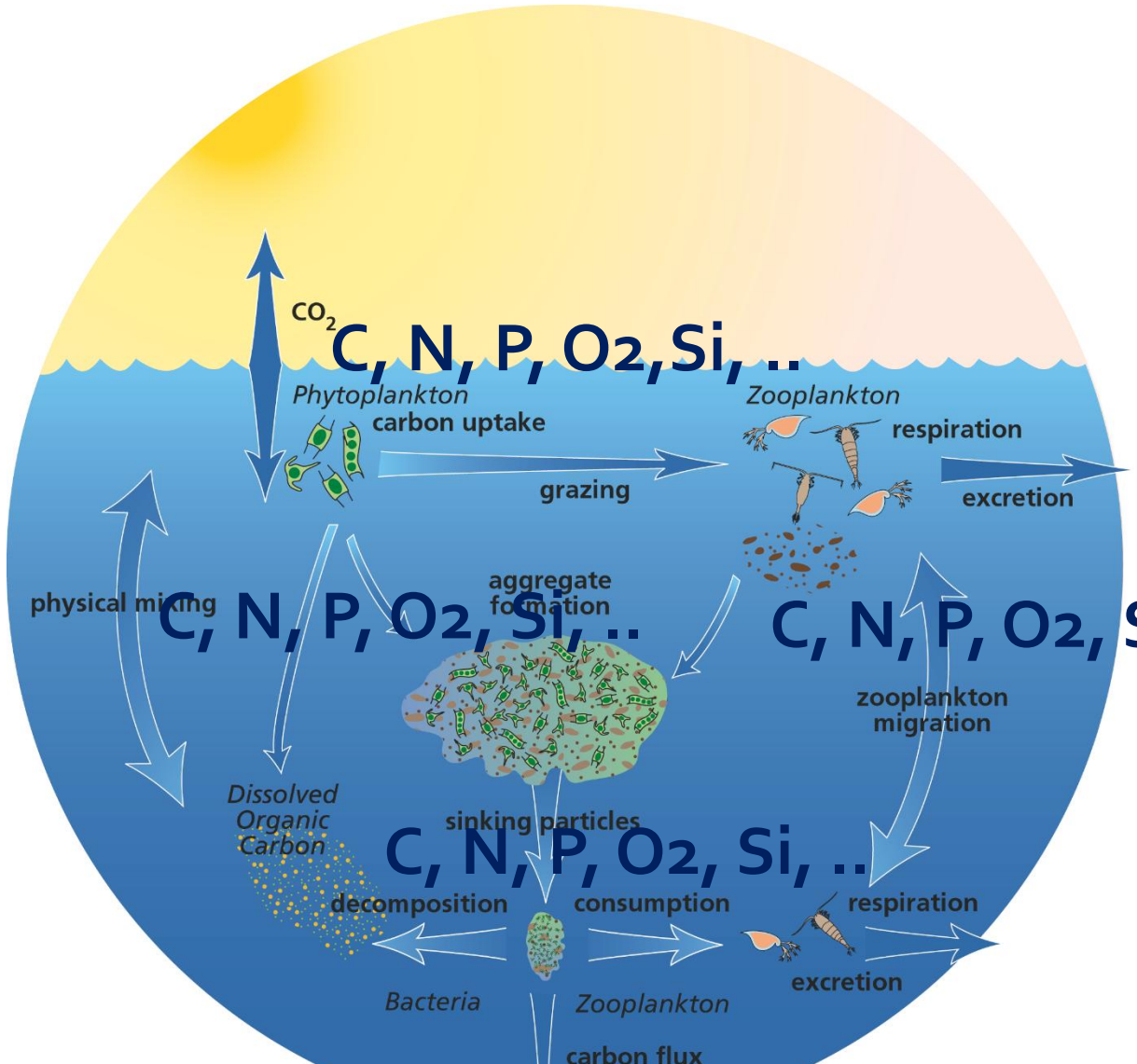
$$\frac{\partial y}{\partial t} + \underbrace{\underline{\nabla}_H \cdot (\underline{u} y) + \frac{\partial}{\partial x_3}(w y)}_{\text{horizontal and vertical advection}} + \underbrace{\frac{\partial}{\partial x_3}(w_y^s y)}_{\text{sedimentation}} = \underbrace{Q^y}_{\text{production / destruction}} + \underbrace{\frac{\partial}{\partial x_3}(\tilde{\lambda}\frac{\partial y}{\partial x_3}) + \lambda_H \nabla_H^2 y}_{\text{horizontal and vertical diffusion}}$$

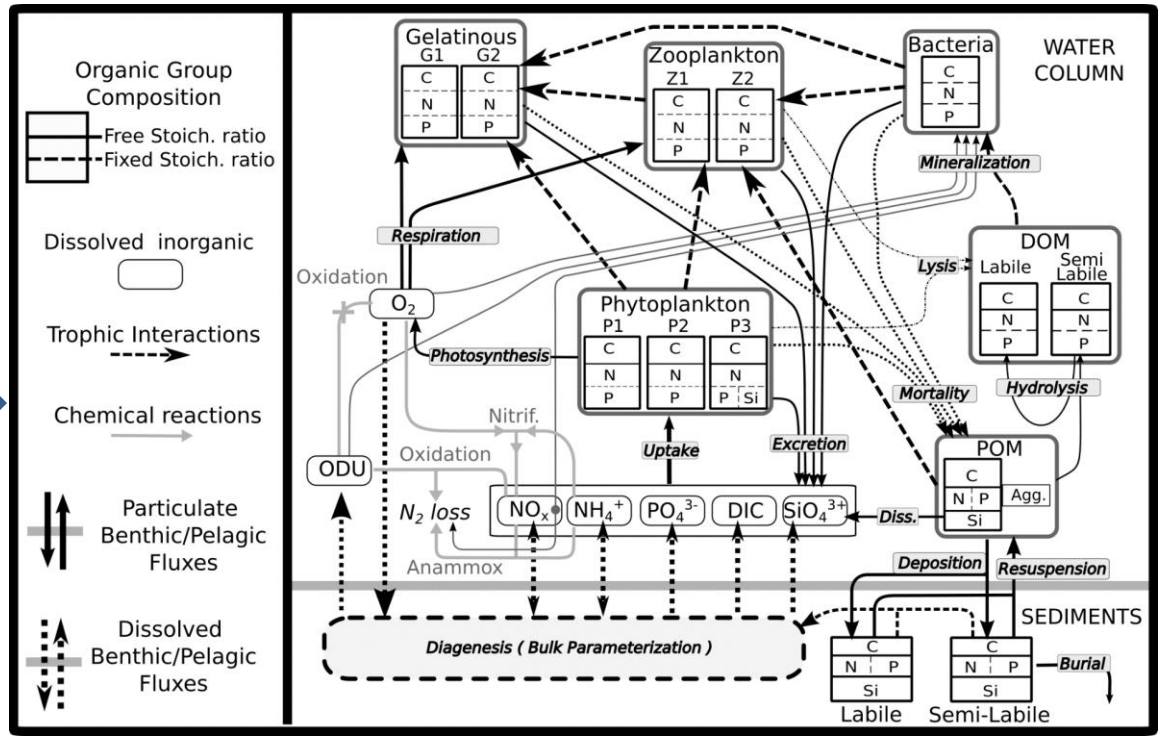

CO_2
Phytoplankton
carbon uptake
grazing
Zooplankton
respiration
excretion
physical mixing
aggregate formation
zooplankton migration
Dissolved Organic Carbon
sinking particles
decomposition
consumption
respiration
excretion
Bacteria
Zooplankton
carbon flux 100m

U.S. JGOFS

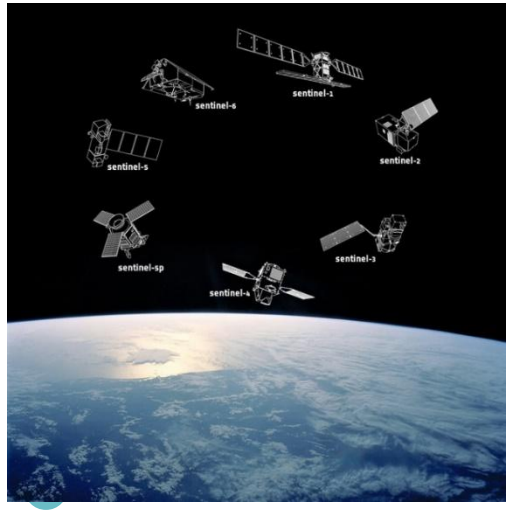

CO_2
C, N, P, O2, Si, ..
Phytoplankton
carbon uptake
Zooplankton
respiration
grazing
excretion
C, N, P, O2, Si, ..
physical mixing
aggregate formation
C, N, P, O2, Si, ..
zooplankton migration
Dissolved Organic Carbon
sinking particles
C, N, P, O2, Si, ..
decomposition
consumption
respiration
excretion
Bacteria
Zooplankton
carbon flux

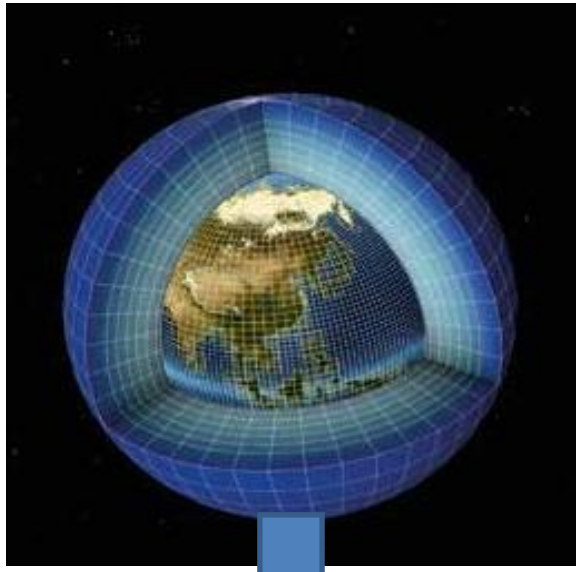
BIOGEOCHEMICAL MODELLING

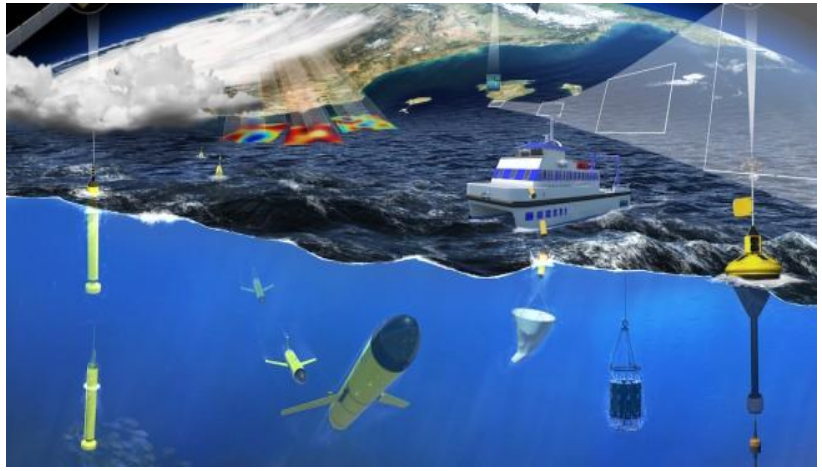


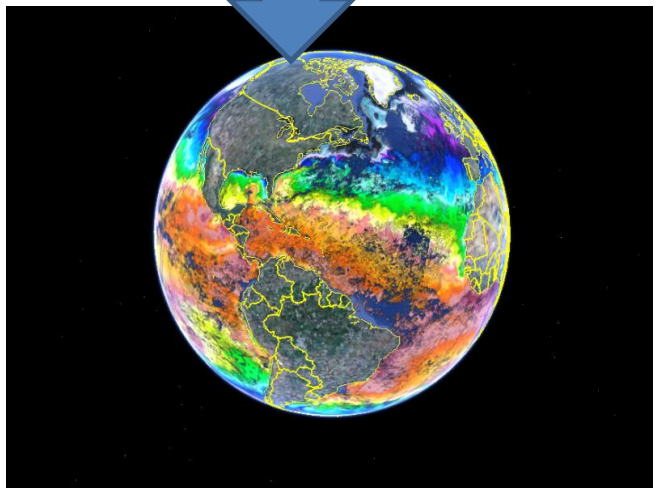


MODEL INTEGRATION









- Initial State
- Evolution equations
- Boundary conditions
- Data Assimilation

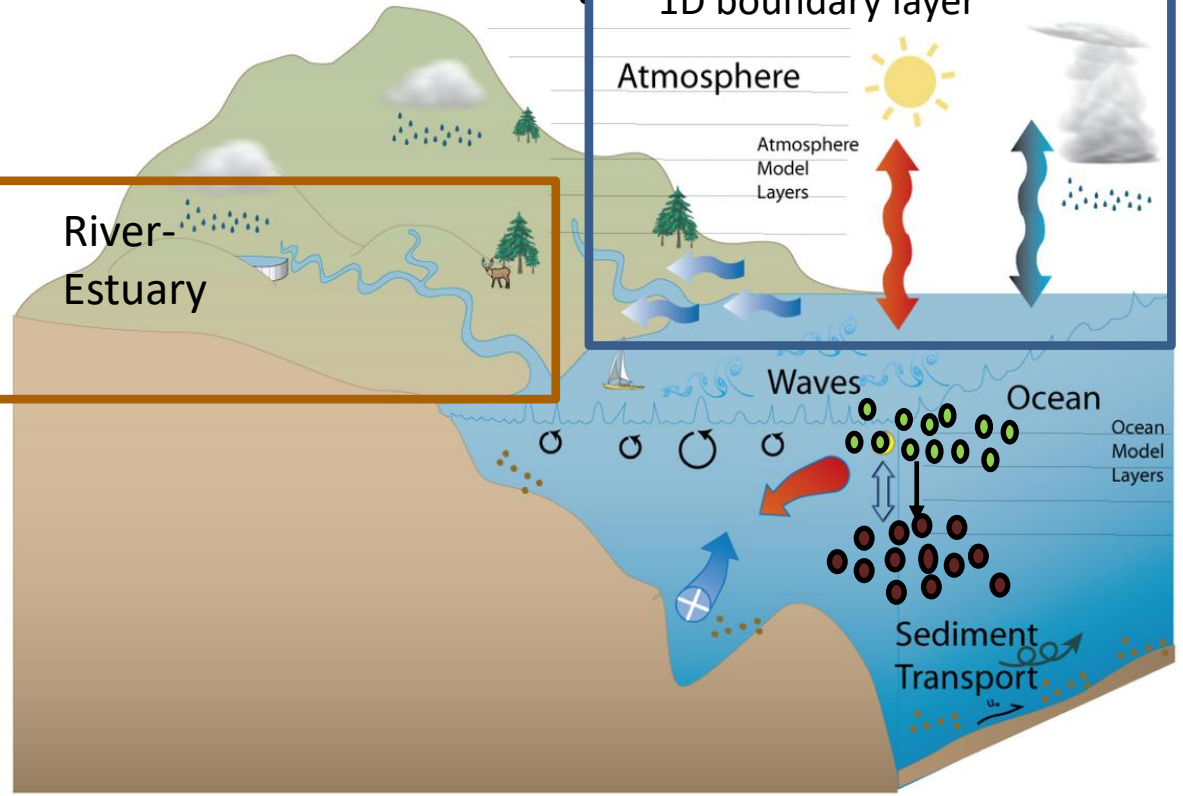
OCEAN –INTERFACES

Atmosphere

- Nutrients deposition
- pCO2
- Radiative information
- 1D boundary layer

Rivers

- Nutrients fluxes
- Suspended materials



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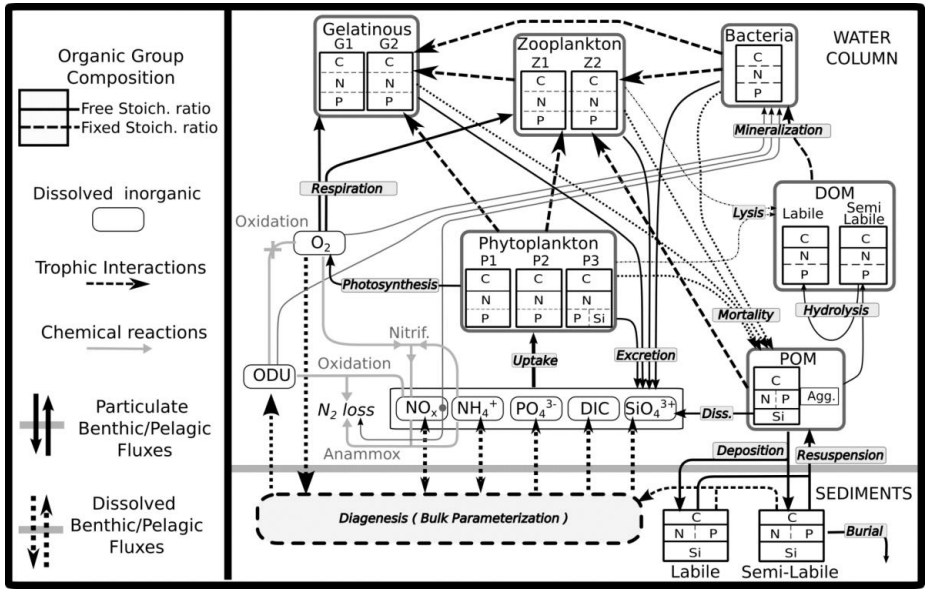
FORECASTING –REANALYSIS

7 regions

- 1. Global
- 2. Arctic
- 3. Baltic
- 4. NWS
- 5. IBI
- 6. Med Sea
- 7. Black Sea

Plankton Functional Types models



Environmental variables

Distributed products :

- Nutrients (NO3, PO4),
- Oxygen
- Plankton: Chla, Phyto in carbon (total and functional groups), Primary Production
- biomass of Zoo in carbon
- Carbonate: pH, DIC, spCO2, fCO2
- Optics (Kd)

Simulations

REANALYSES

~25 years

FORECAST

5 to 10 days

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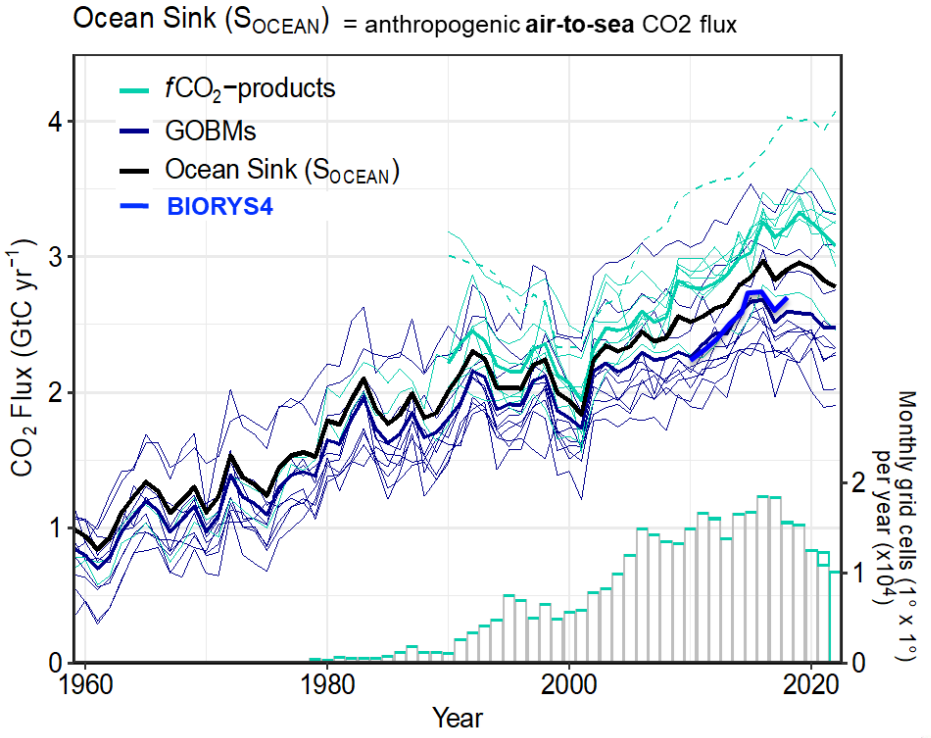
GLOBAL OCEAN CARBON SEQUESTRATION

Preliminary results:
- ✓ Efficient control of CHL and nutrients
- ✓ Significant improvements in carbonate chemistry variables
- ✓ Encouraging results on air-to-sea CO2 flux estimation

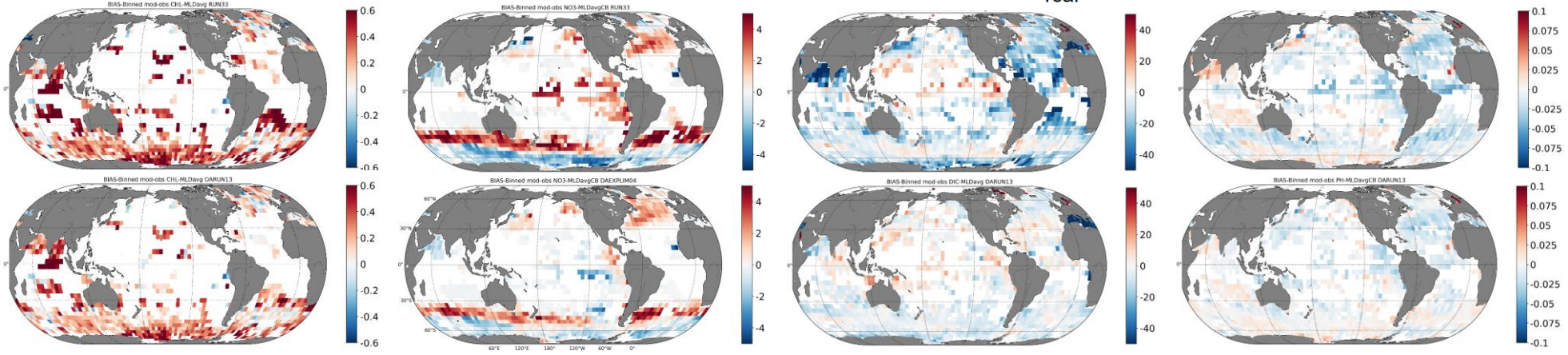


Chl **NO3**

CONTROL (assimilated dynamics, no BGC/carbonates data assimilation, no relaxation)

BIORYS4

Bias (model vs BGCArgo database) 2009-2018



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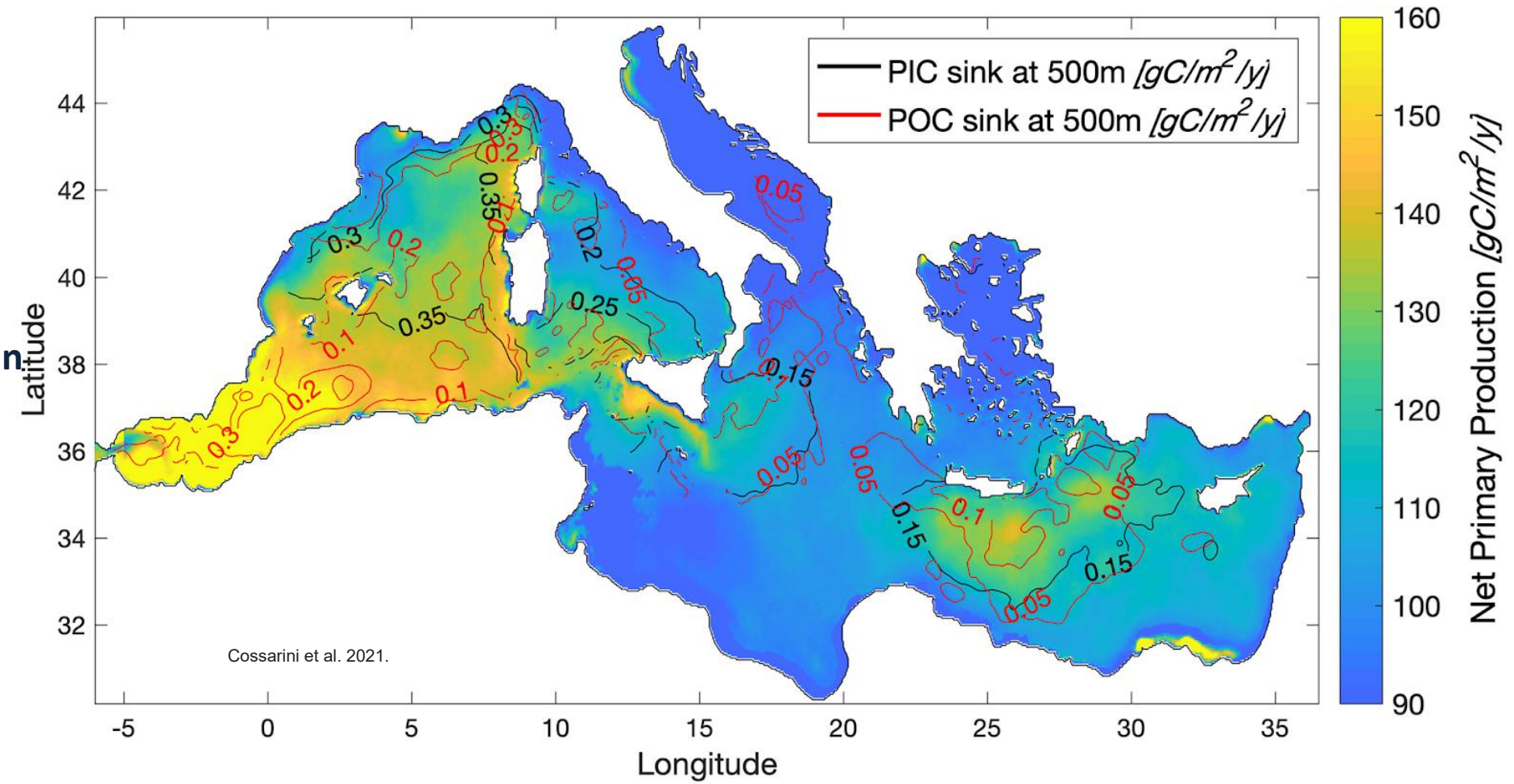
MEDITERRANEAN SEA PRODUCTIVITY

Marine productivity and contribution of the biological (POC) and carbonate (PIC) pumps to the sink of organic carbon into the Mediterranean interior



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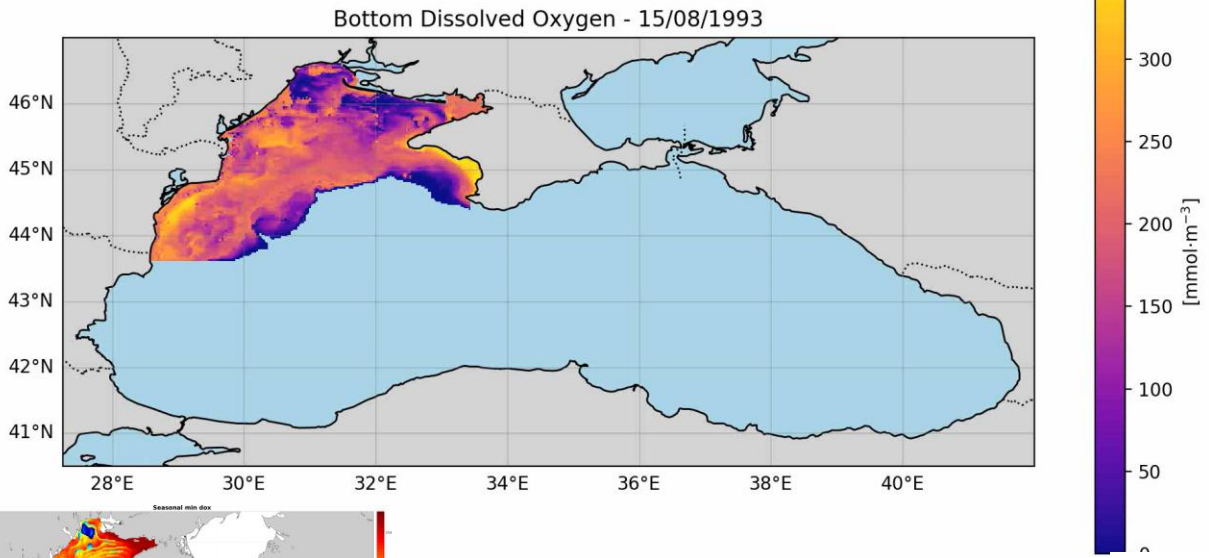
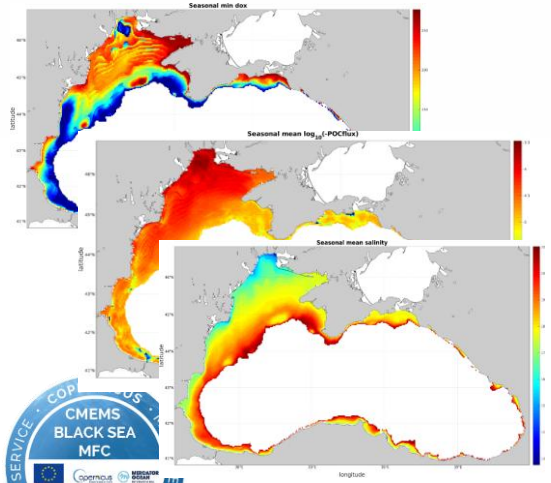
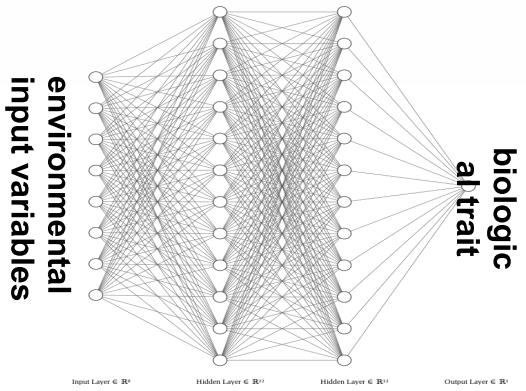
BLACK SEA OXYGEN and BIODIVERSITY

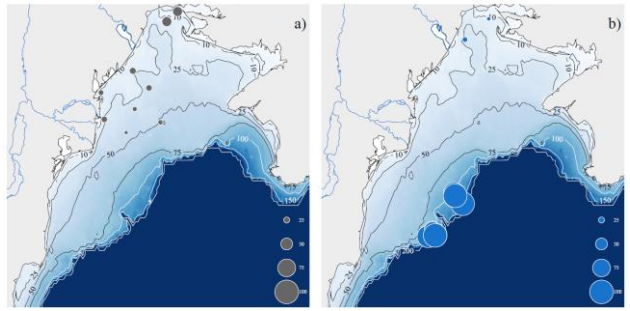
Marine Hypoxia (O2<63 µmol/l) on the Black Sea's northwestern shelf in summer



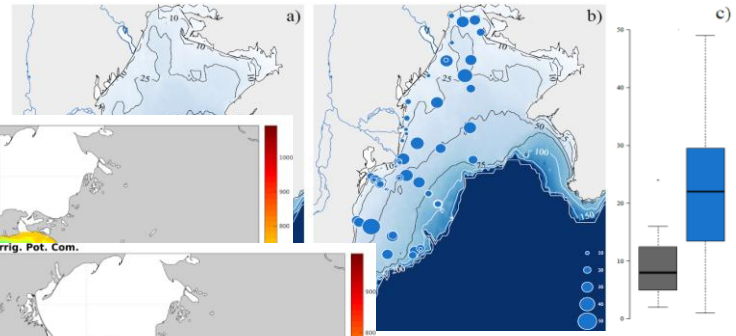


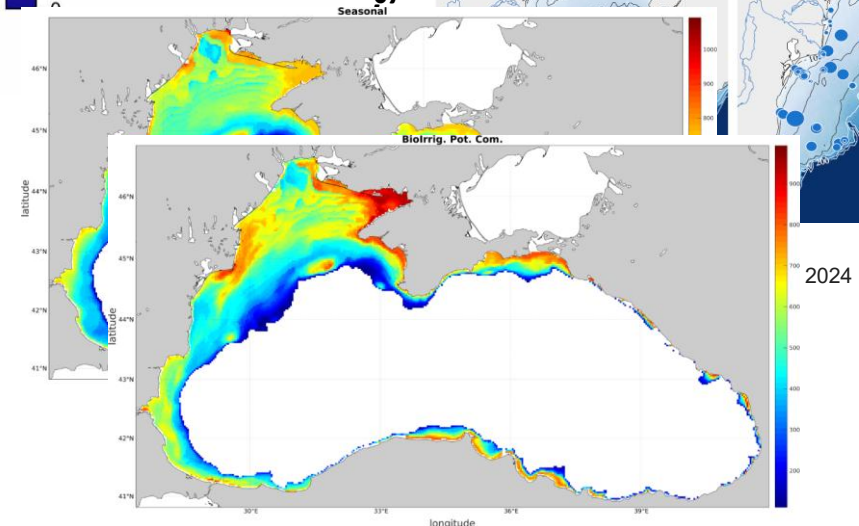


Days with hypoxic conditions in the 90s (left) and 2010s (right) (CMEMS REANALYSIS)



Species richness in the 90s (left) and 2010s (right)





2024

CMEMS BLACK SEA MFC

NECCTON
NEW COPERNICUS CAPABILITY FOR TROPHIC OCEAN NETWORKS

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BLACK SEA ENVIRONMENT and BIOLOGY

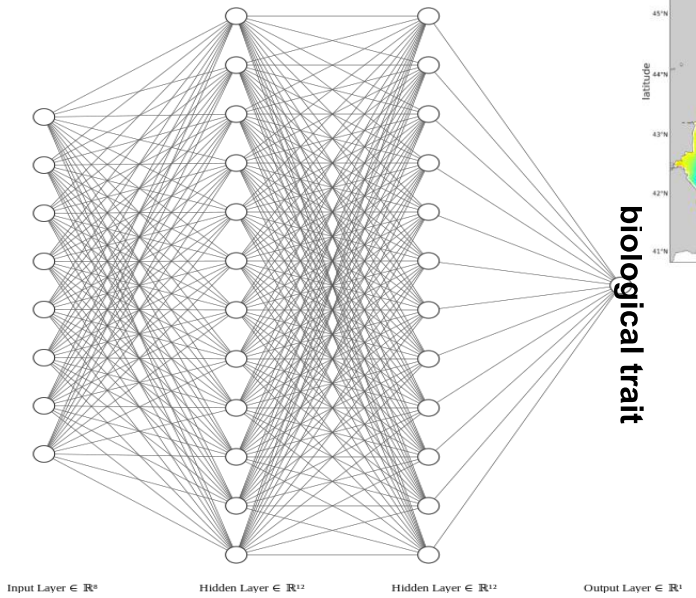
Oxygen (min)

POC (log (mean))

Salinity (mean)

Temperature (mean)

environmental input variables



biological trait

BPc

IPc

Rew3

NECCTON
NEW COPERNICUS CAPABILITY FOR TROPHIC OCEAN NETWORKS

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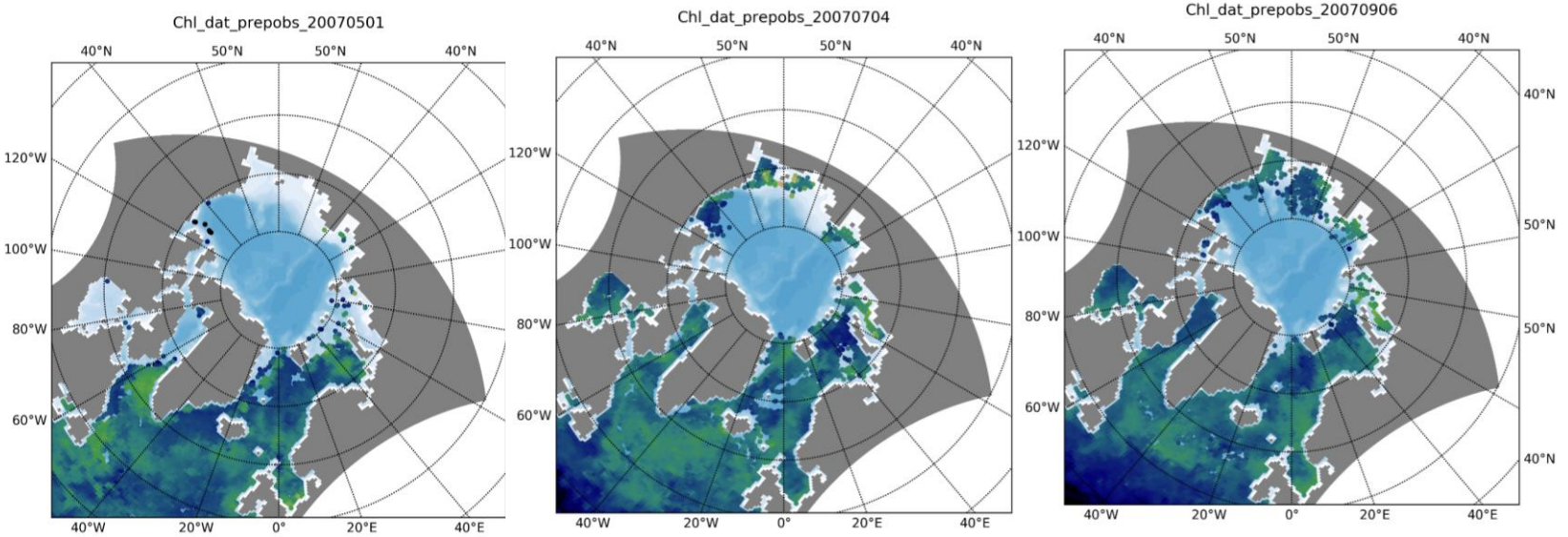
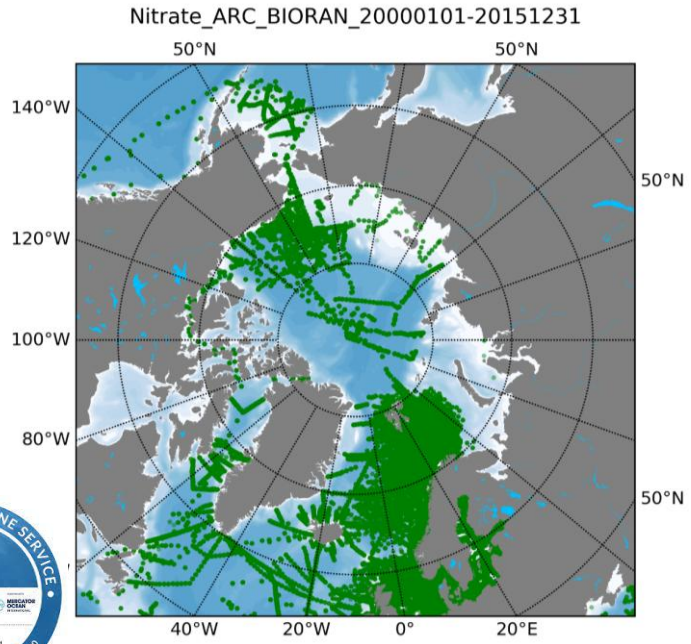
ARCTIC OCEAN CHLOROPHYLL

BIORAN System:

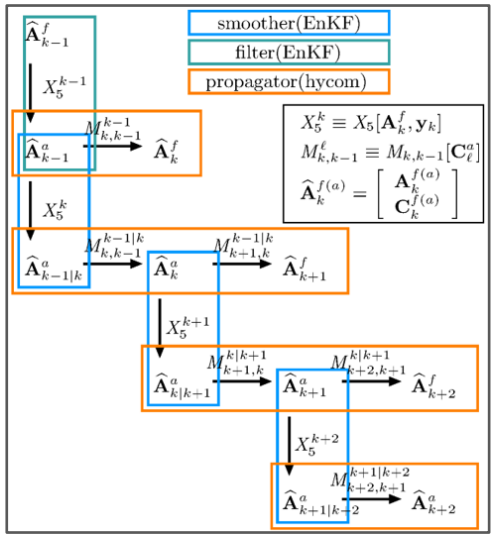
HYCOM-FABM-ECOSMO
Fixed lag EnKS (smoother)
BGC State-Parameter joint estimation
Gaussian Anamorphosis in Chl-a observation

Assimilated Data:
Satellite Chl-a (ESA OC CCI 8 daily)
In-situ nutrients (Nitrate,Silicate,Phosphate)
Source: GLODAPv2, ICES, NMDC, Clivar

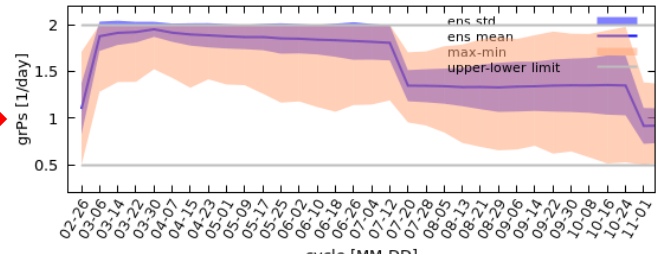




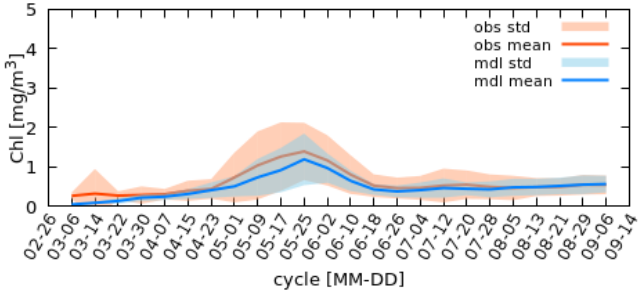
in-situ nutrients



parameter



state



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