NECCTON

NEW COPERNICUS CAPABILITY FOR TROPHIC OCEAN NETWORKS

How including bio-optics improves biogeochemical models: present and future perspectives

P. Lazzari, OGS

This project has received funding from Horizon Europe RIA under Grant Number 101081273

MEAP Meeting – 6th September, 2023

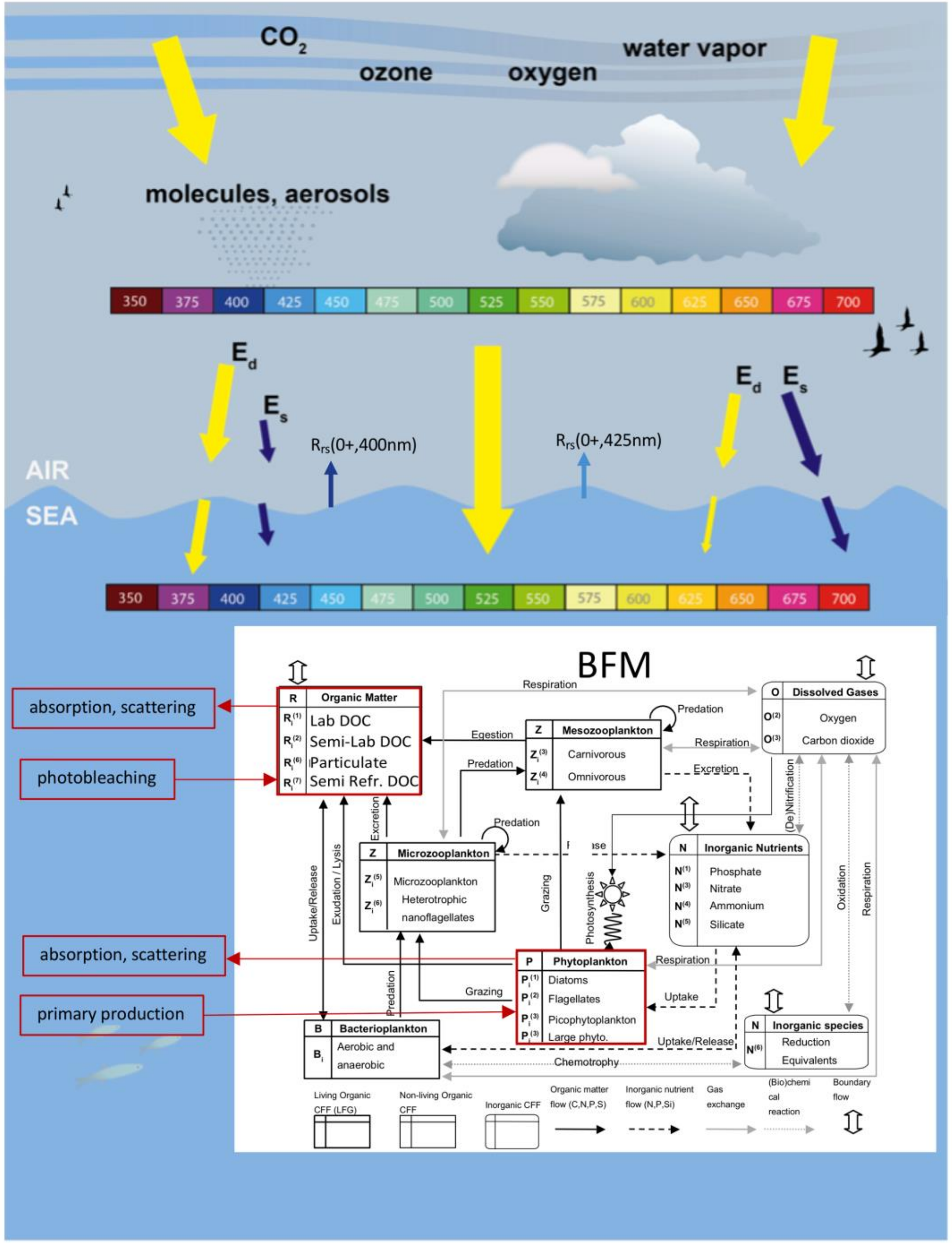
Outline

- Definition of Bio-optical model in Multispectral formulation
- Application within the Mediterranean Sea
- *Future perspectives*.

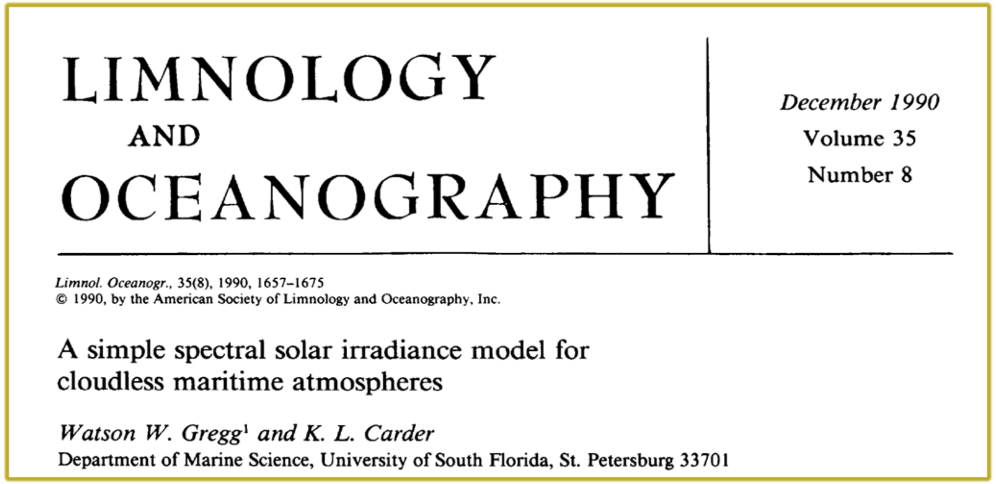
Bio-optical model

Main components

- Atmospheric component
- In-water component
- Interaction with biology and optically active substances



OASIM atmospheric model



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AND
OCEANOGRAPHY

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Number 8

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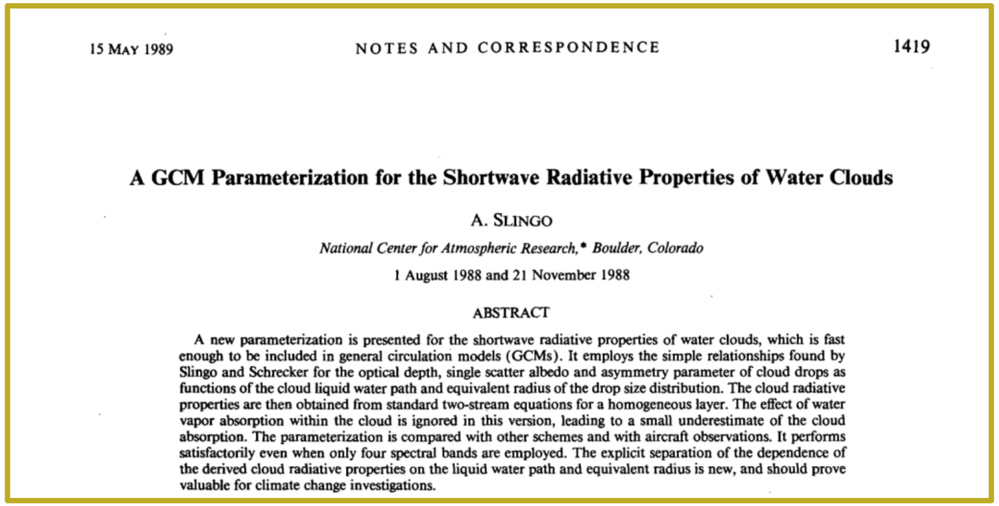
A simple spectral solar irradiance model for cloudless maritime atmospheres

Watson W. Gregg[1] *and K. L. Carder*
Department of Marine Science, University of South Florida, St. Petersburg 33701



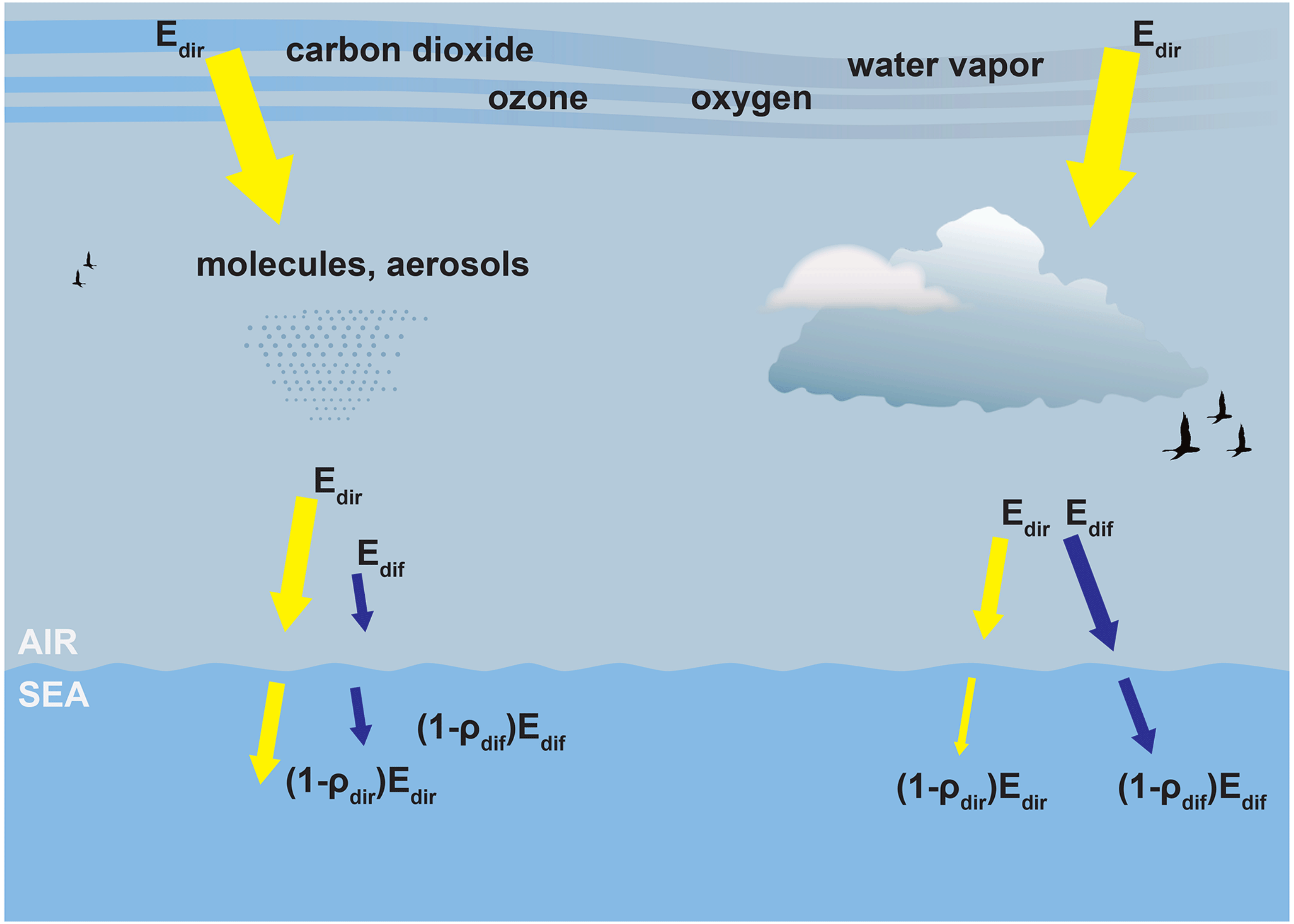
15 May 1989 NOTES AND CORRESPONDENCE 1419

A GCM Parameterization for the Shortwave Radiative Properties of Water Clouds

A. Slingo
National Center for Atmospheric Research, Boulder, Colorado*
1 August 1988 and 21 November 1988

ABSTRACT

A new parameterization is presented for the shortwave radiative properties of water clouds, which is fast enough to be included in general circulation models (GCMs). It employs the simple relationships found by Slingo and Schrecker for the optical depth, single scatter albedo and asymmetry parameter of cloud drops as functions of the cloud liquid water path and equivalent radius of the drop size distribution. The cloud radiative properties are then obtained from standard two-stream equations for a homogeneous layer. The effect of water vapor absorption within the cloud is ignored in this version, leading to a small underestimate of the cloud absorption. The parameterization is compared with other schemes and with aircraft observations. It performs satisfactorily even when only four spectral bands are employed. The explicit separation of the dependence of the derived cloud radiative properties on the liquid water path and equivalent radius is new, and should prove valuable for climate change investigations.



33 wavelengths from 0 to 4 um, 25 nm res. in 400-700 nm

IN-WATER 3-stream model


frontiers in Marine Science

ORIGINAL RESEARCH
published: 06 March 2017
doi: 10.3389/fmars.2017.00060

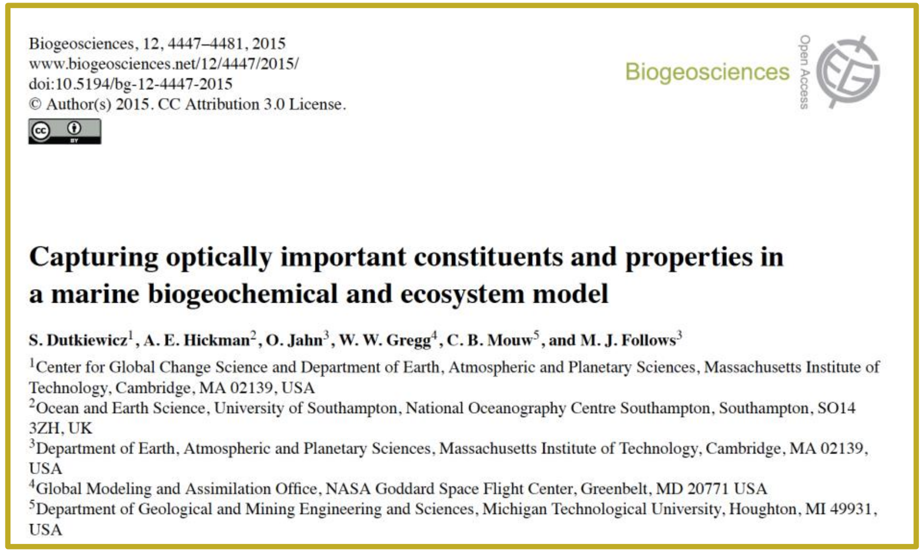
Check for updates

Simulating PACE Global Ocean Radiances

*Watson W. Gregg * and Cécile S. Rousseaux*

NASA Global Modeling and Assimilation Office, Greenbelt, MD, USA

The NASA PACE mission is a hyper-spectral radiometer planned for launch in the next decade. It is intended to provide new information on ocean biogeochemical constituents by parsing the details of high resolution spectral absorption and scattering. It is the first of its kind for global applications and as such, poses challenges for


Biogeosciences, 12, 4447–4481, 2015
www.biogeosciences.net/12/4447/2015/
doi:10.5194/bg-12-4447-2015
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Biogeosciences
Open Access

Capturing optically important constituents and properties in a marine biogeochemical and ecosystem model

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[2]Ocean and Earth Science, University of Southampton, National Oceanography Centre Southampton, Southampton, SO14 3ZH, UK
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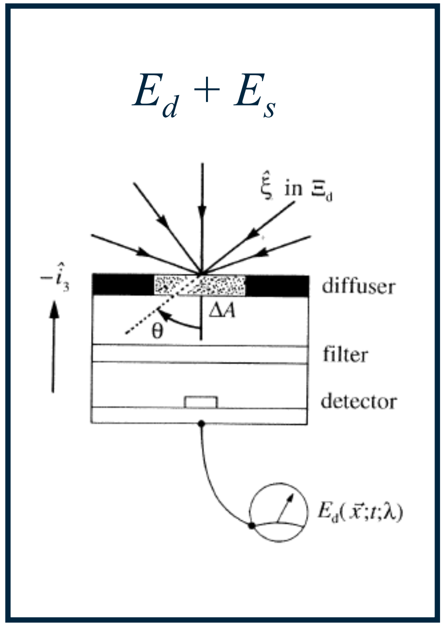
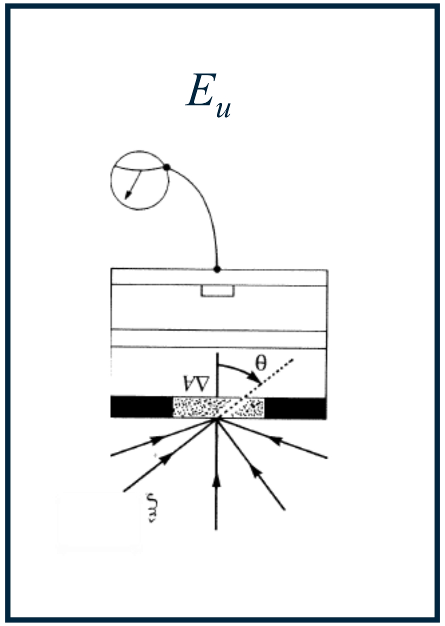
[5]Department of Geological and Mining Engineering and Sciences, Michigan Technological University, Houghton, MI 49931, USA

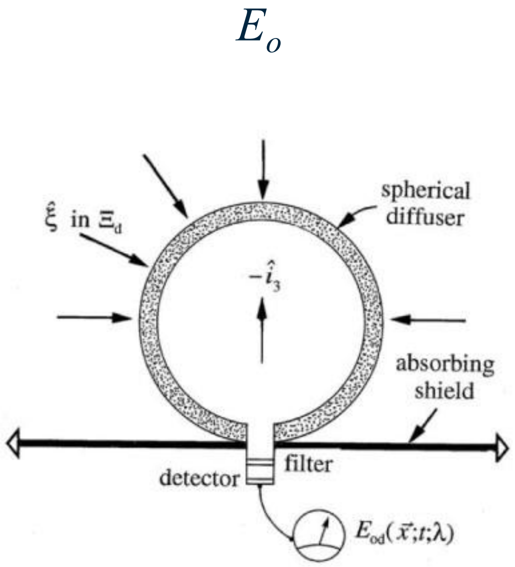
$$\frac{dE_d}{dz} = -\frac{a+b}{\cos\theta_d}E_d$$

$$\frac{dE_s}{dz} = -\frac{a+r_s b_b}{\bar{v}_s}E_s + \frac{r_u b_b}{\bar{v}_u}E_u + \frac{b - r_d b_b}{\cos\theta_d}E_d$$

$$-\frac{dE_u}{dz} = -\frac{a+r_u b_b}{\bar{v}_u}E_u + \frac{r_s b_b}{\bar{v}_s}E_s + \frac{r_d b_b}{\cos\theta_d}E_d$$







Ed, Es
BOUSSOLE
BGC ARGO FLOAT

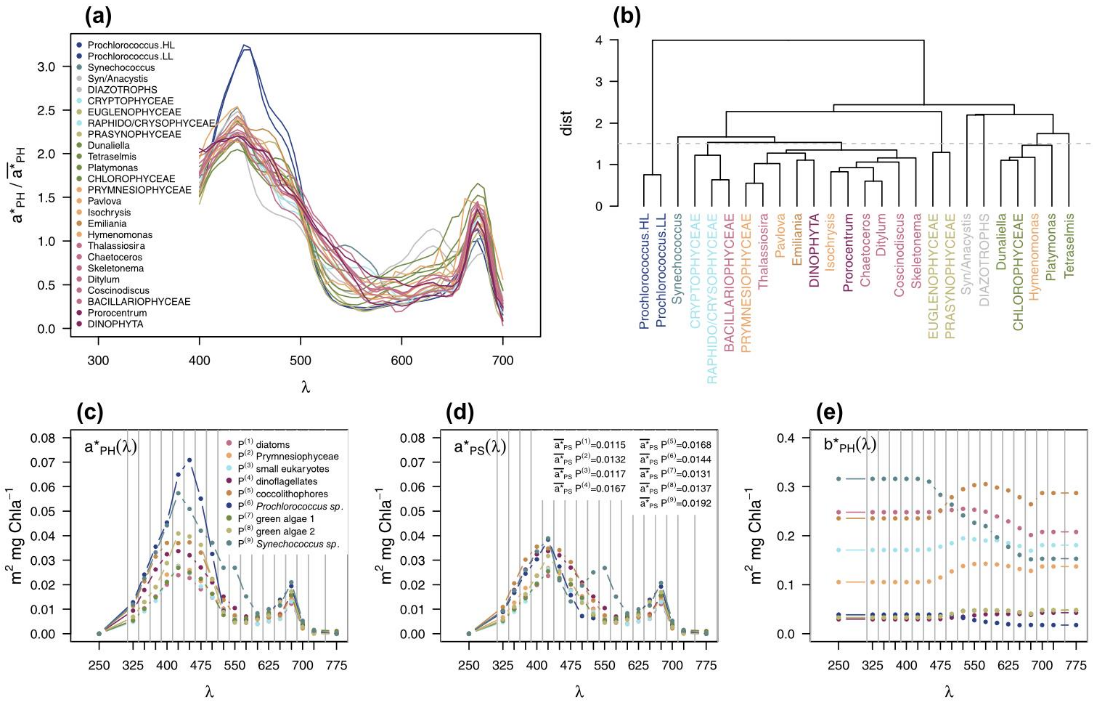
Eu(0-)
[+ Ed(0-), Es(0-)]
Compute R_{rs}

E_0
Compute PAR/PUR
for BGC models

Absorption and scattering

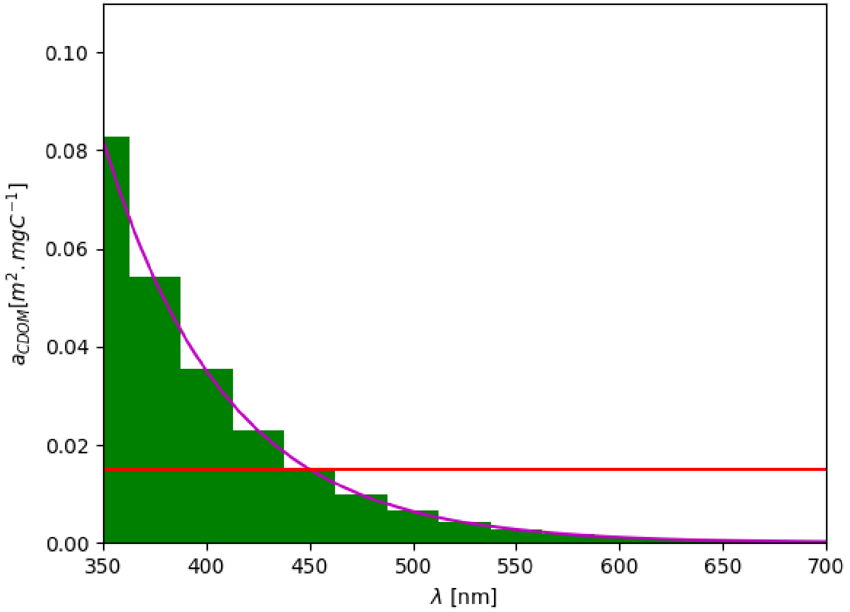
$$
\begin{aligned}
a_\lambda &= a_{w,\lambda} + a_{\mathrm{PH},\lambda} \cdot chla + a_{CDOM,\lambda} \cdot CDOM + a_{NAP,\lambda} \cdot NAP \\
b_\lambda &= b_{w,\lambda} + b_{PH,\lambda} \cdot C + b_{NAP,\lambda} \cdot NAP \\
b_{b,\lambda} &= b_{b,w,\lambda} + b_{b,PH,\lambda} \cdot C + b_{b,NAP,\lambda} \cdot NAP
\end{aligned}
$$

Phyto



Álvarez et al., 2021

CDOM



Applications

Trends Detection, Dutkiewicz et al., 2019

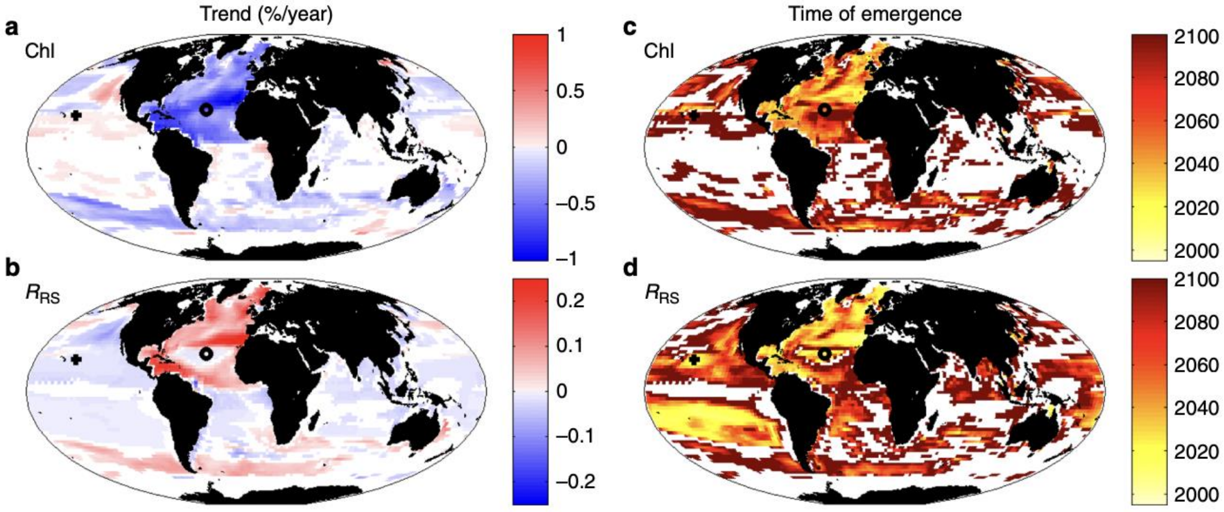
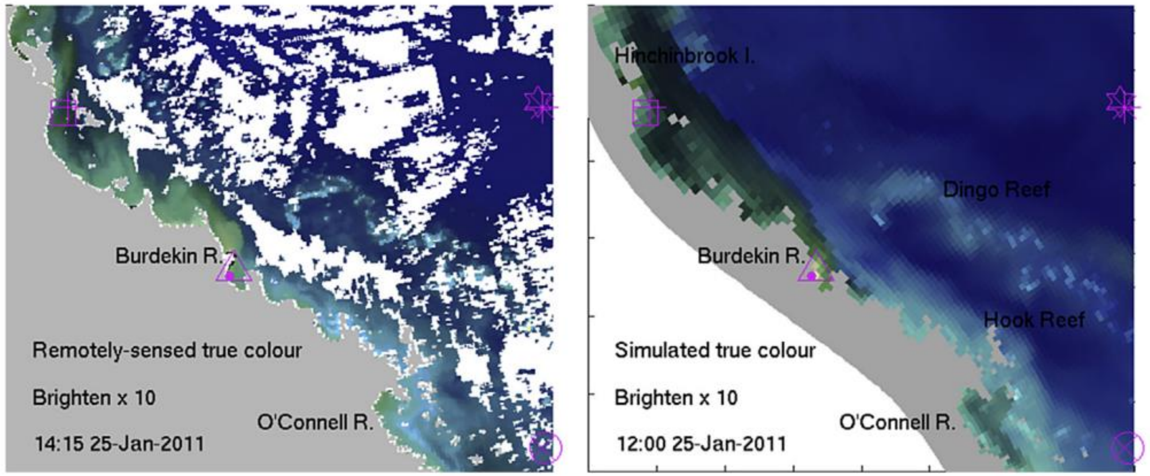


Fig. 9 Trends and time of emergence. Model linear trend (%/year) for **a** actual Chl-a, and **b** remotely sensed reflectance at 475 nm; and time of emergence of trend for **c** Chl-a, and **d** R_{RS} at 475 m. A generalized least squares (GLS) fit was used to quantify the trends. Only regions with statistically significant ($p <$ 0.05) trends over the 21st century and that were largely ice-free in the current day (as model R_{RS} are only valid for such regions) are shown. The symbols (+,o) indicate two locations highlighted in Fig. 8

True color, Baird et al., 2016

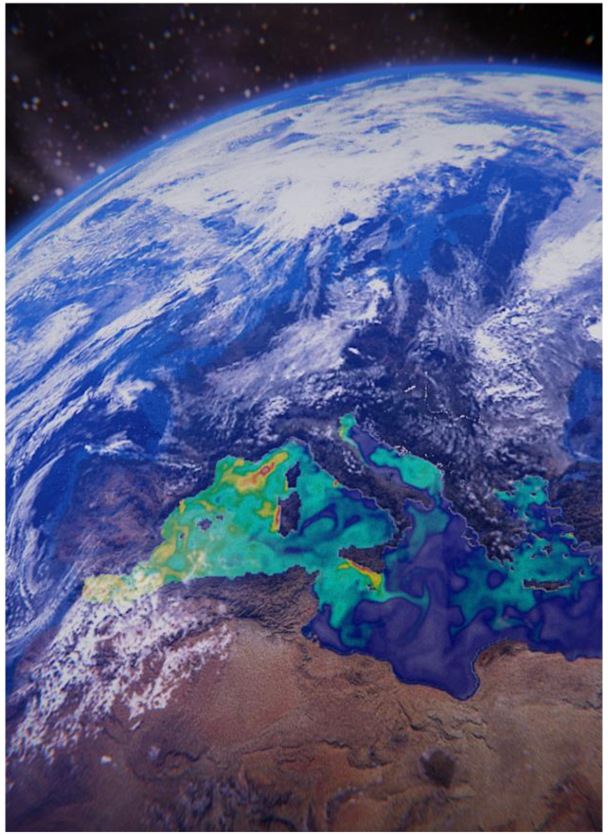


Applications in The Mediterranean Sea

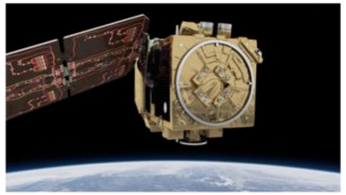
The OGS contribute to the Copernicus Marine Services (CMS)

Copernicus Marine Service in a nutshell

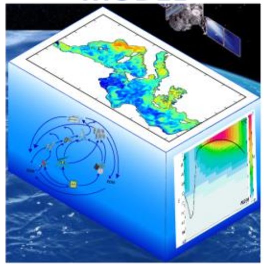
- CMS provides free, open, regular and systematic reference information on the blue (physical), white (sea ice), and green (biogeochemical) ocean state, variability and dynamics across the global ocean and European regional seas.
- Implemented by Mercator Océan International
- OGS produces past, present and future information on the **biogeochemical state of the Mediterranean Sea** (nutrients, chlorophyll, oxygen, carbon cycle, pH, plankton…) using the **MedBFM**, a **model system** which **couples physics with biogeochemstry** and assimilates data from satellite and floats



SATELLITE



MODEL

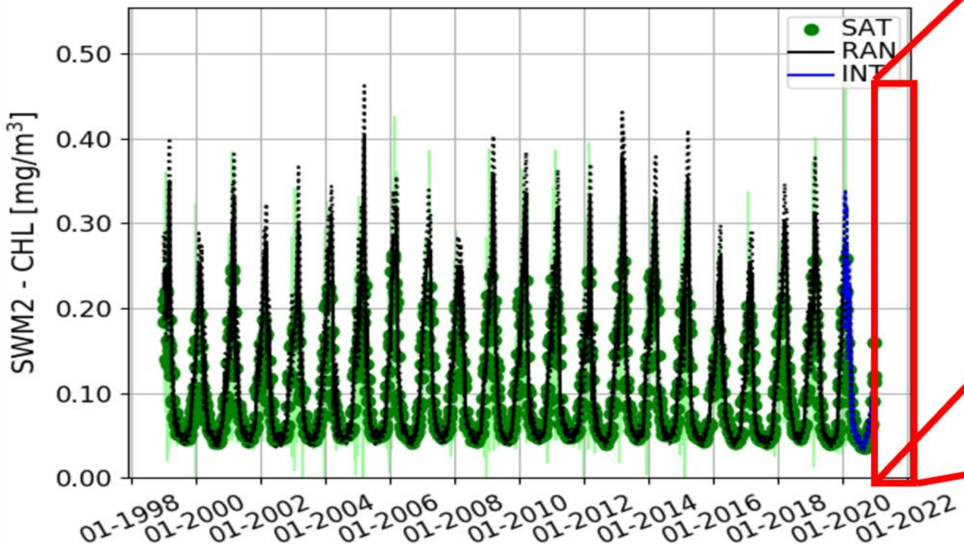


IN SITU

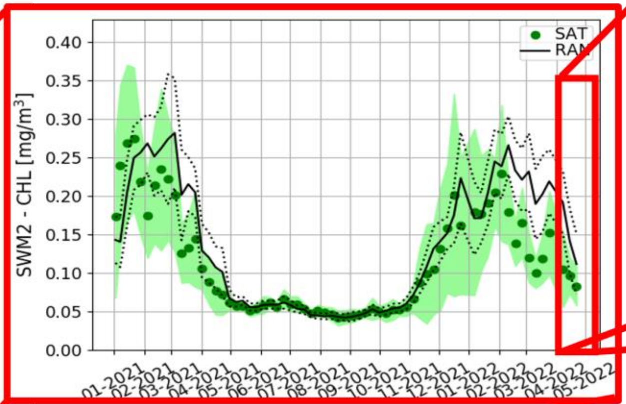
Biogeochemical state of Med'Sea in the past, present and future

REANALYSIS	INTERIM	ANALYSIS & FORECAST
1999... – ... 2020	Jan 2021... – May 2022	14-6-2022 – 30-6-2022

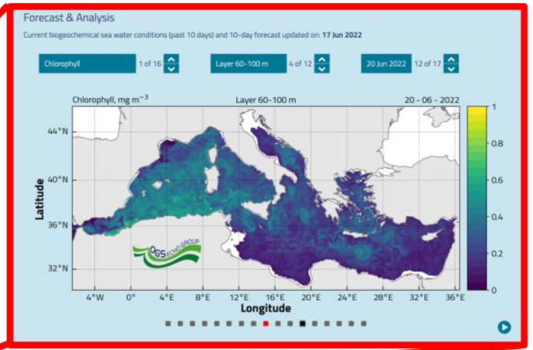
Outlook of biogeochemical evolution and variability in the recent decades



Outlook of last year



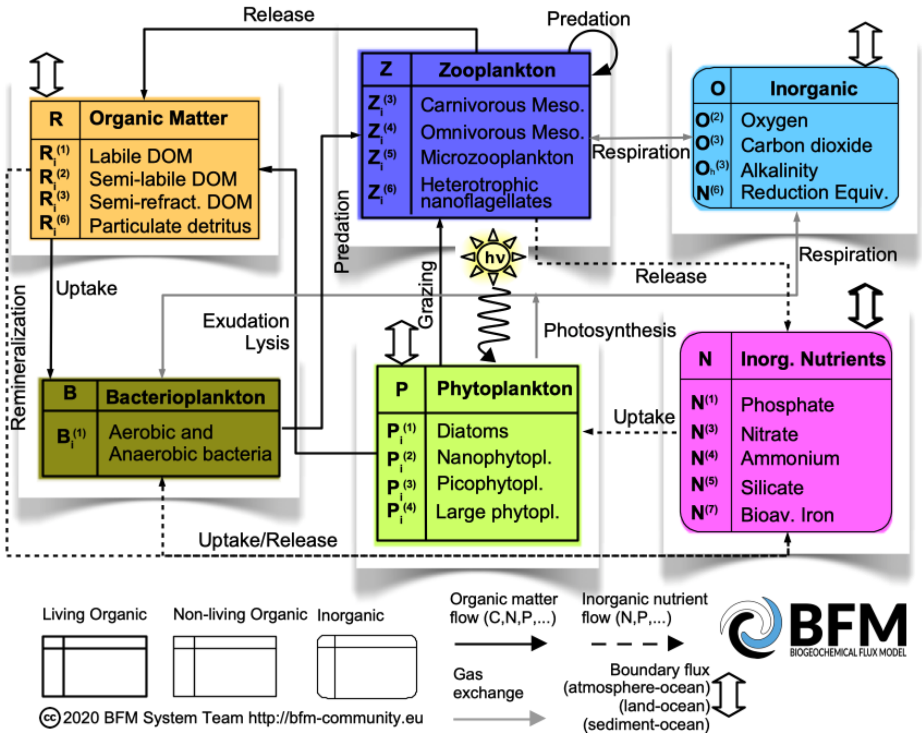
Outlook of present and near future

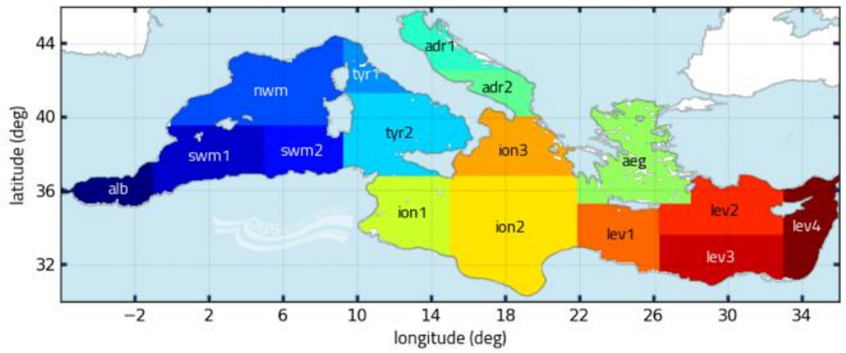


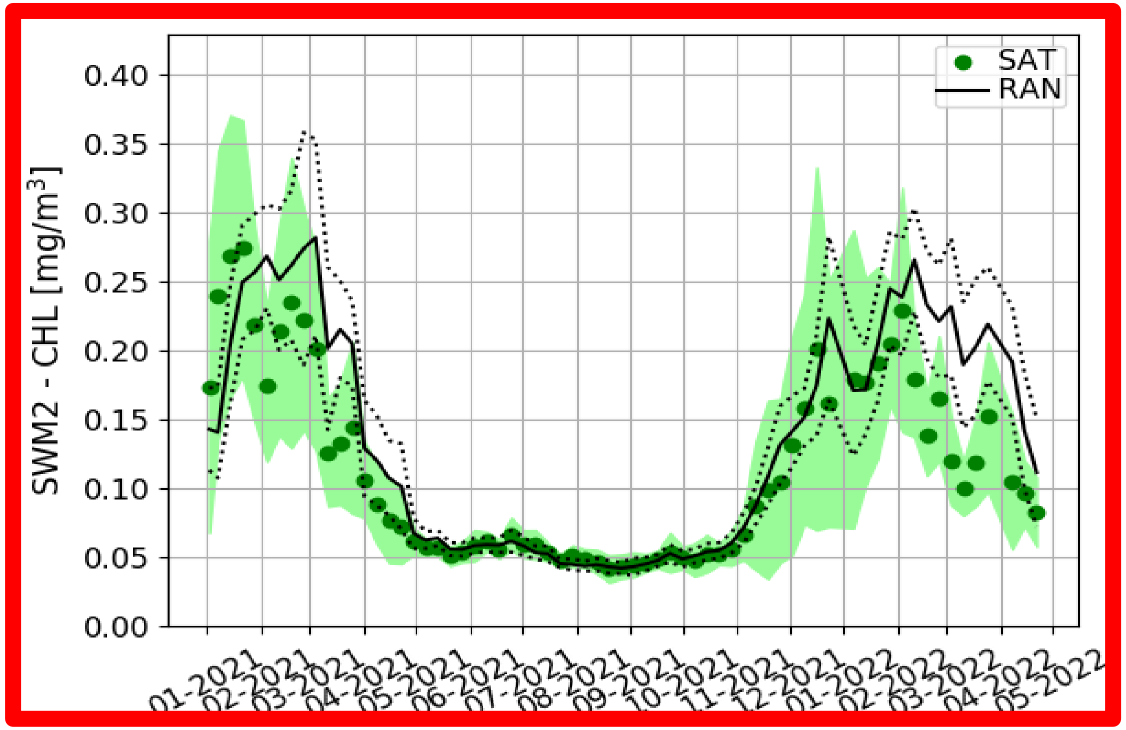
http://medeaf.ogs.it/

MEAP Meeting – 6th September, 2023

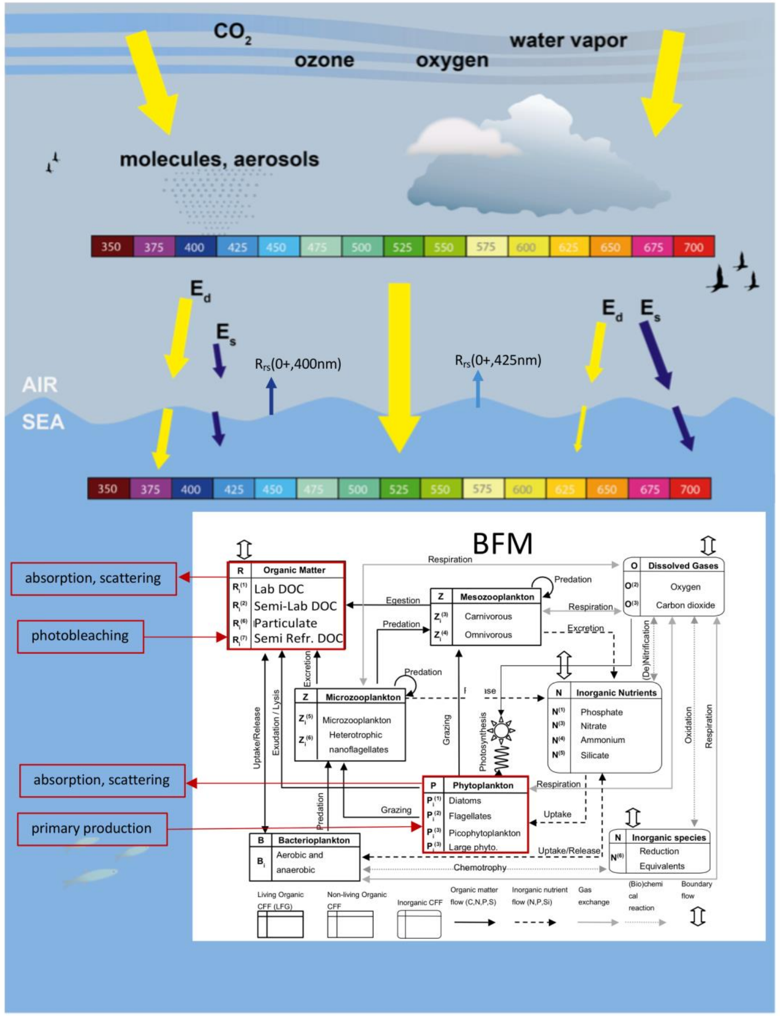
Chla as diagnostic

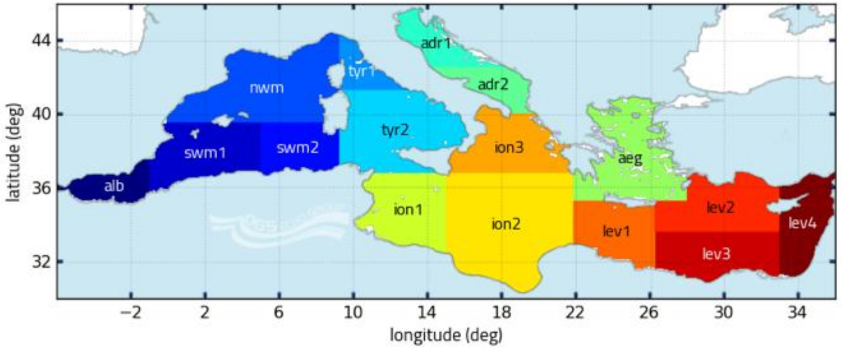


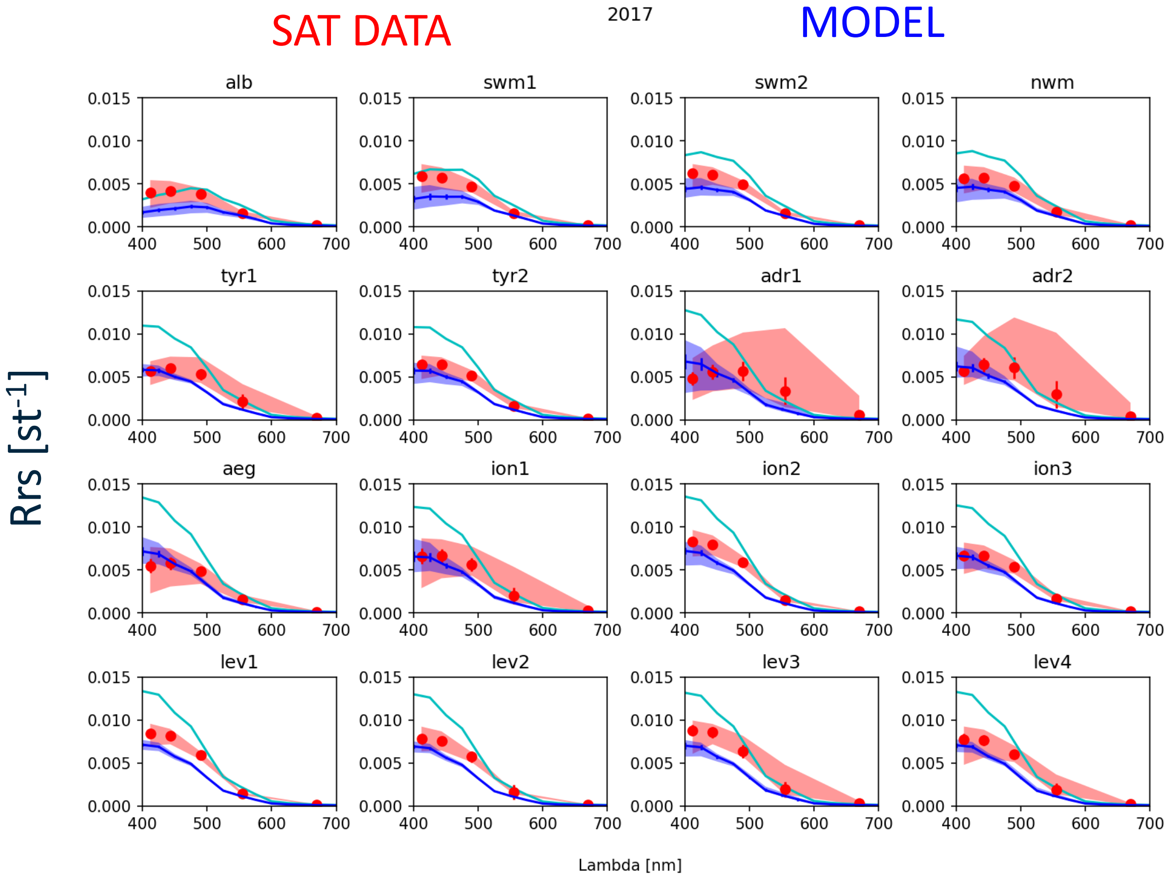




Rrs as diagnostic

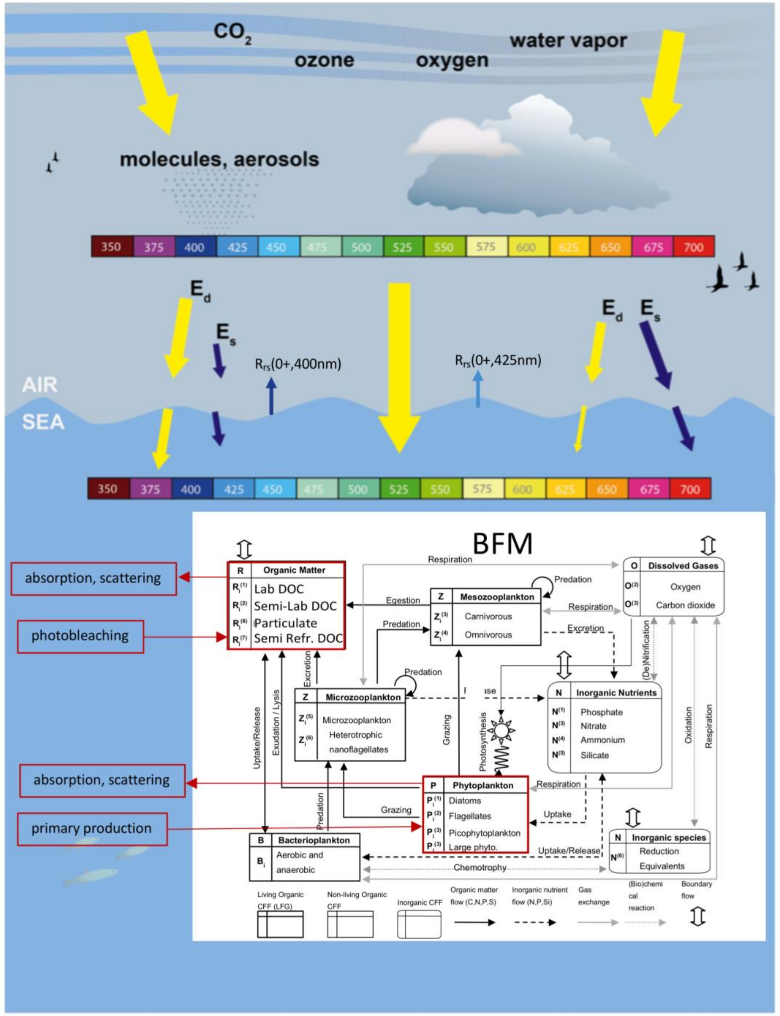


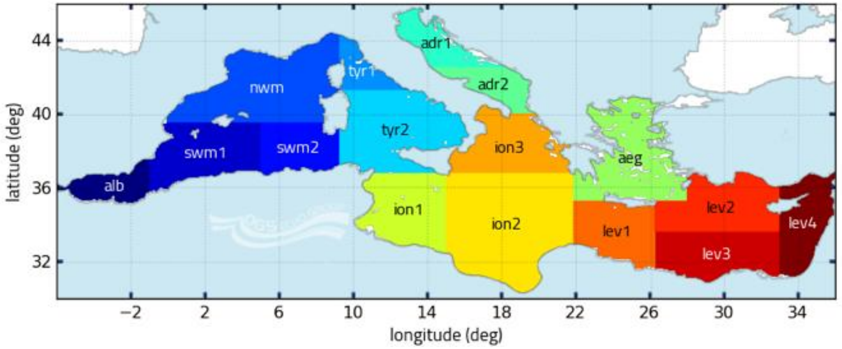




Lazzari et al., 2021

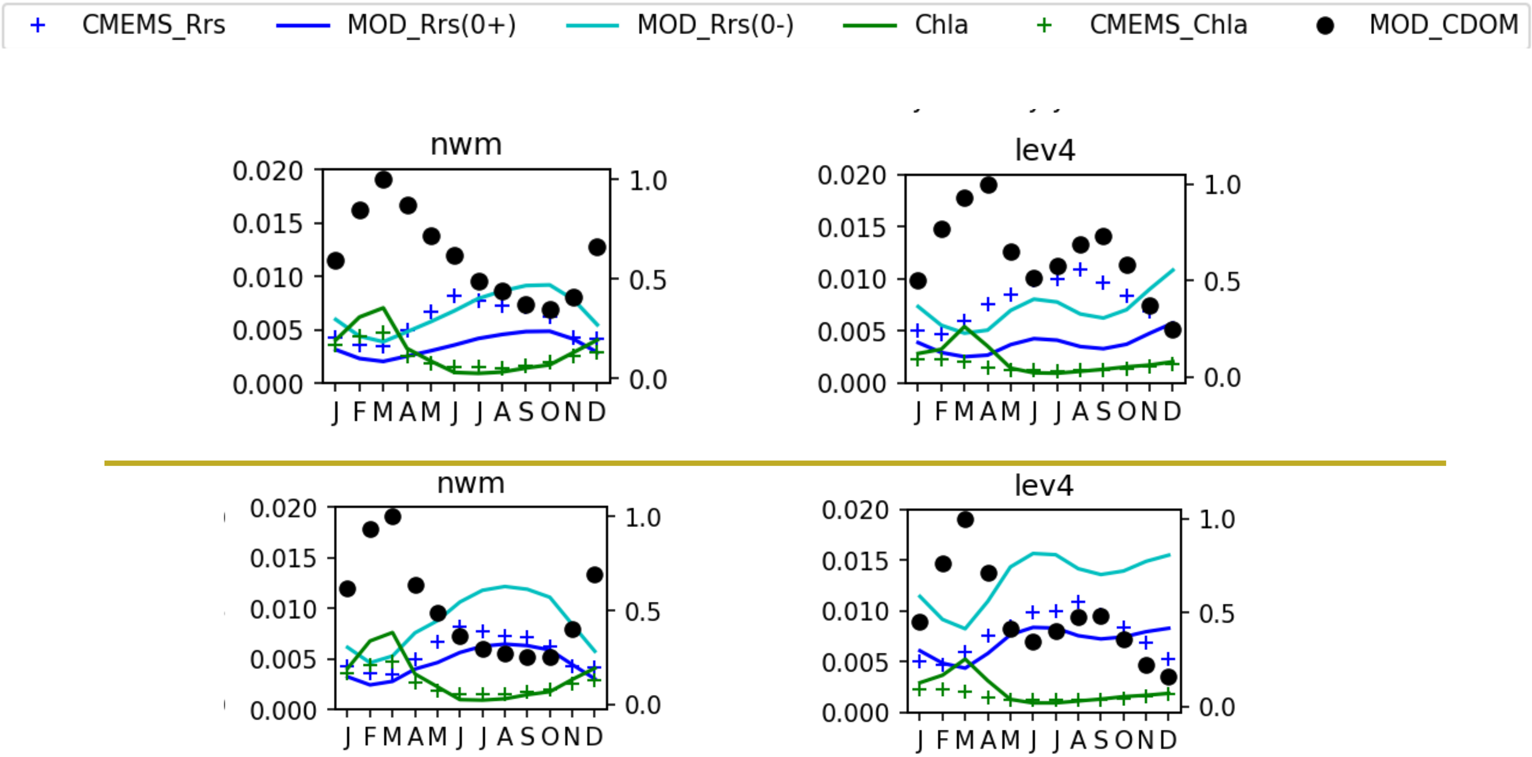
Rrs as diagnostic





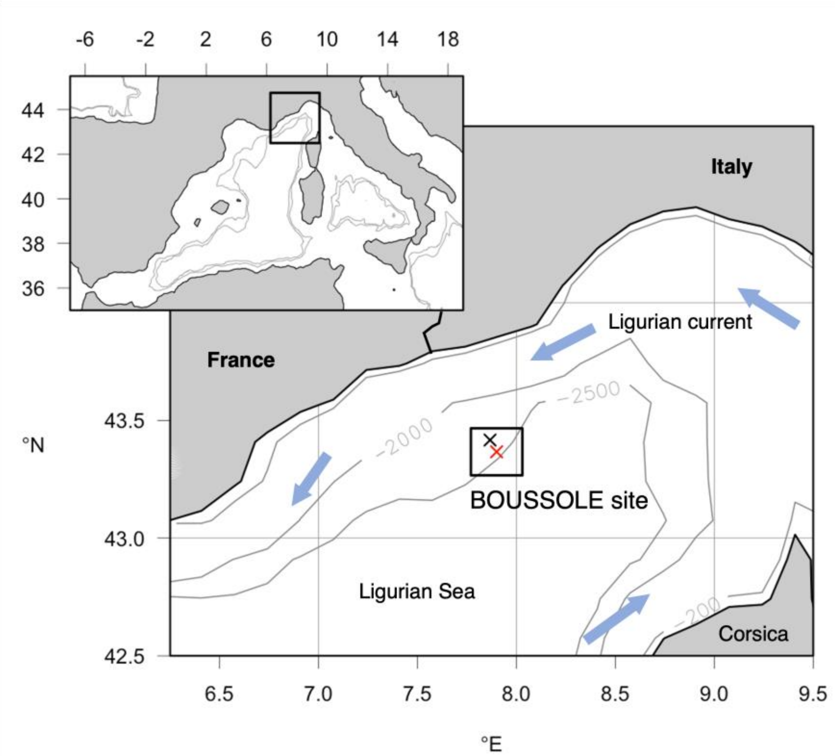
SAT DATA

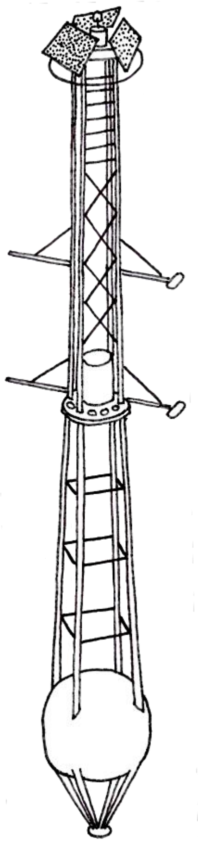
MODEL

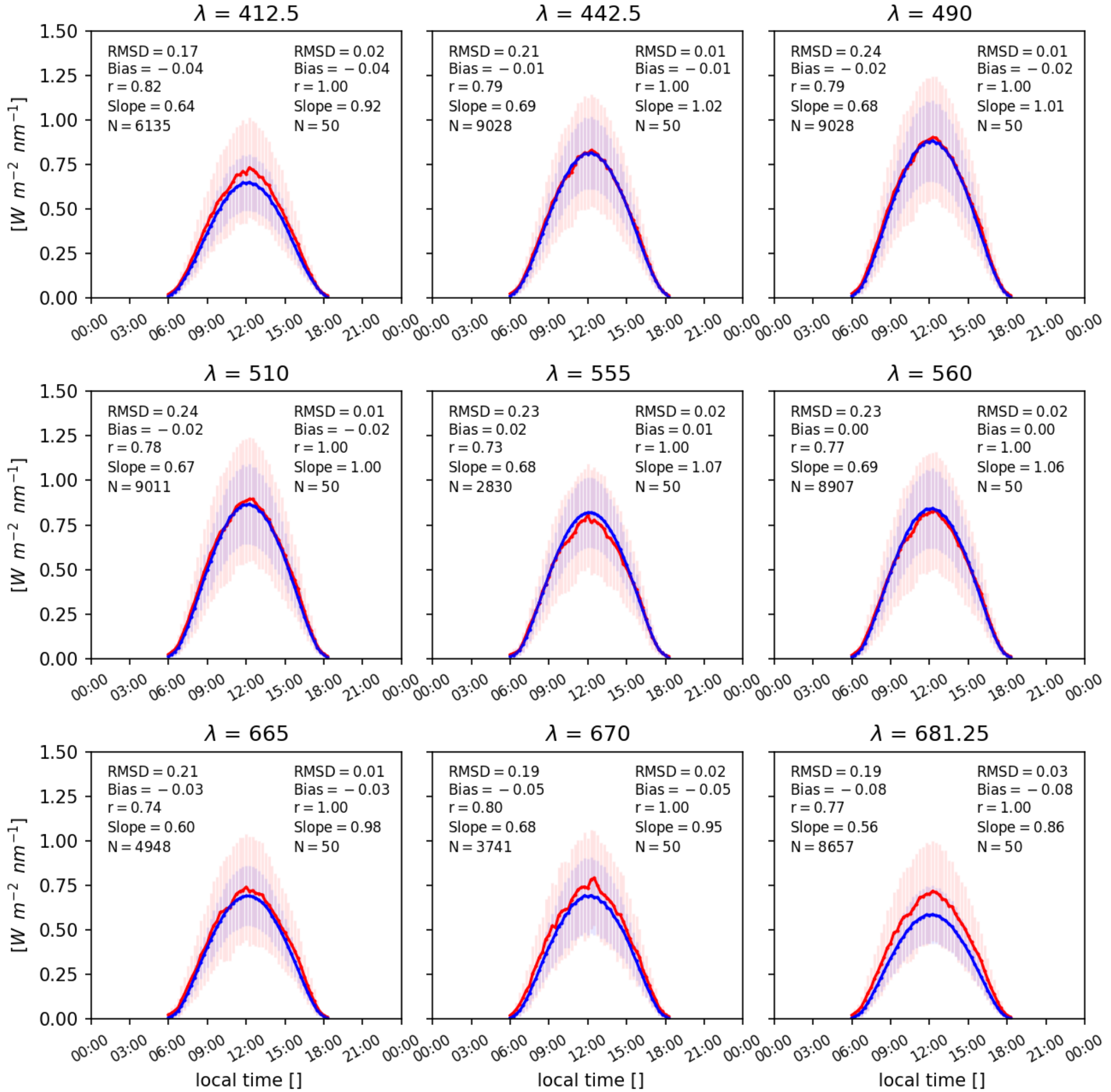


Lazzari et al., 2021

OASIM Validation at BOUSSOLE site





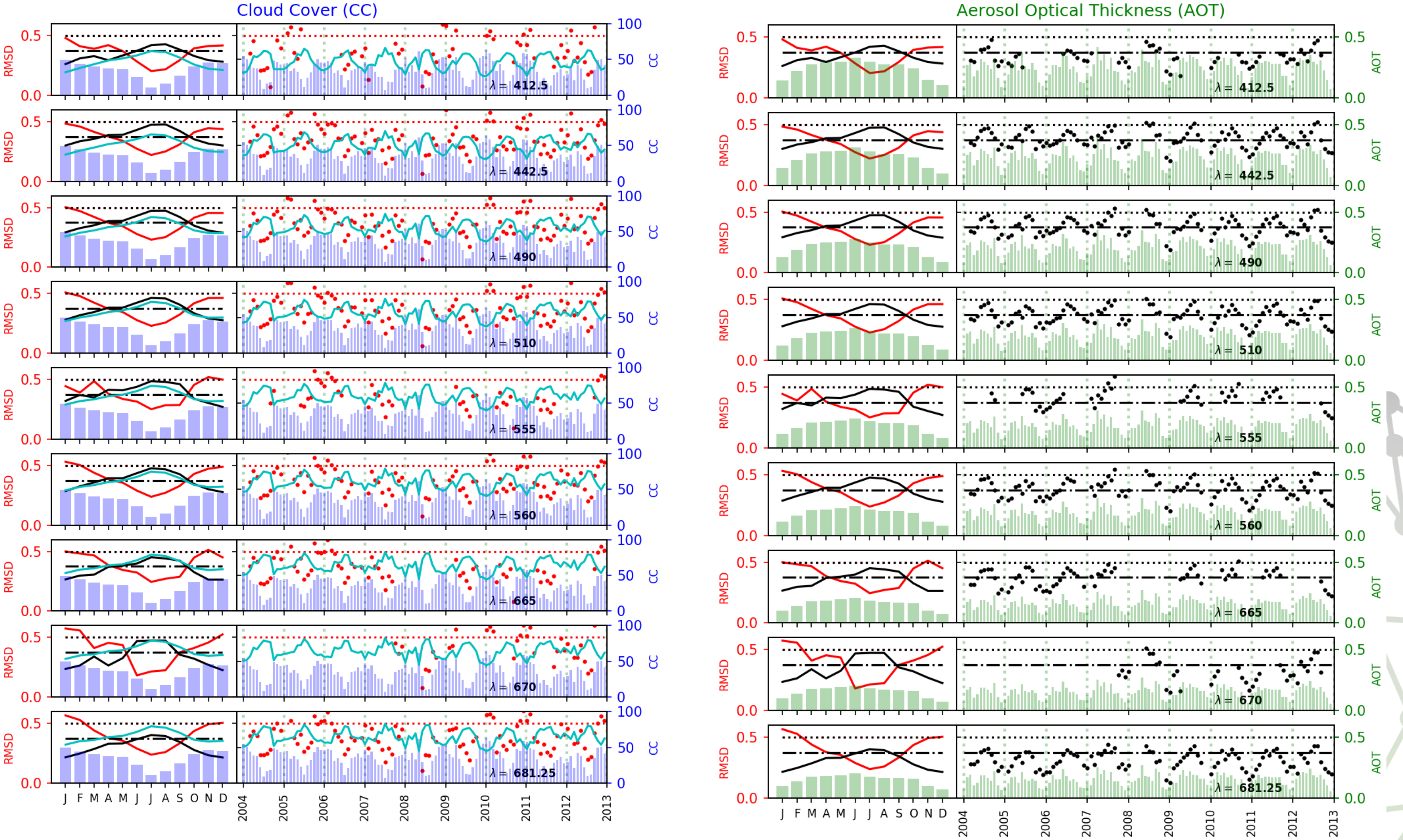


- ‘BOUSSOLE project’ observational data:

Buoy for high frequency radiometric measurements.

Lazzari et al., 2021

OASIM Validation at BOUSSOLE site



Lazzari et al., 2021

1D CDOM STUDIES

NECCTON

- SEAMLESS prototype (GOTM-FABM-BFM) and ParSAC tools:

SEAMLESS

Framework for Aquatic Biogeochemical Models

biogeochemistry
BFM
+
hydrodynamics
GOTM

Light transmission resolved in 33 λ

Parallel Sensitivity Analysis and Calibration tools
+
1D configuration (depth) to simulate specific sites

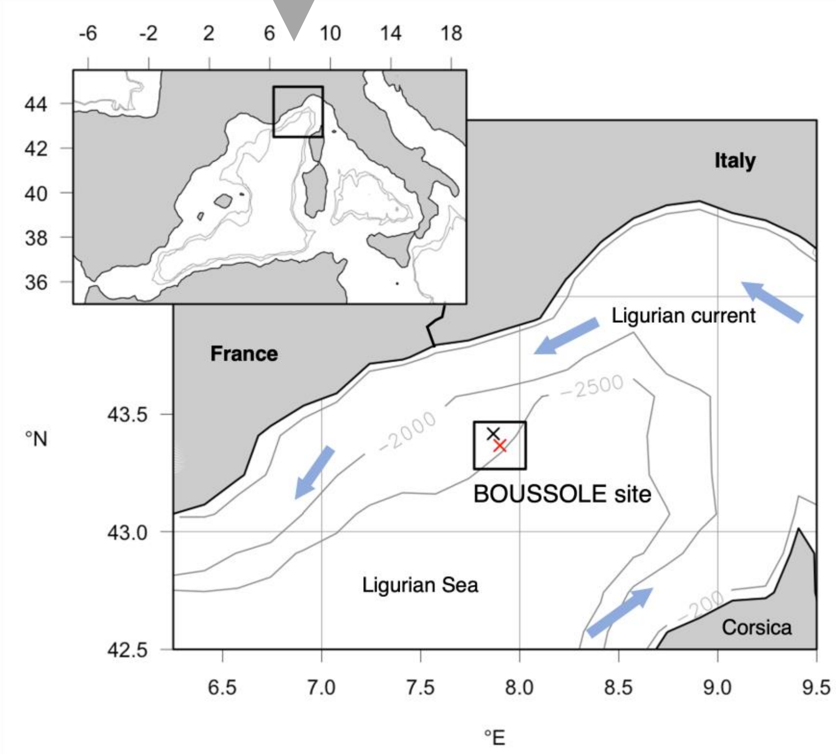
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776480

- 'BOUSSOLE project' observational data:

Buoy for high frequency radiometric measurements.

× Monthly cruises: Chlorophyll, HPLC pigments and IOPs: $a_{PH}(\lambda)$, $a_{NAP}(\lambda)$ & $a_{CDOM}(\lambda)$.

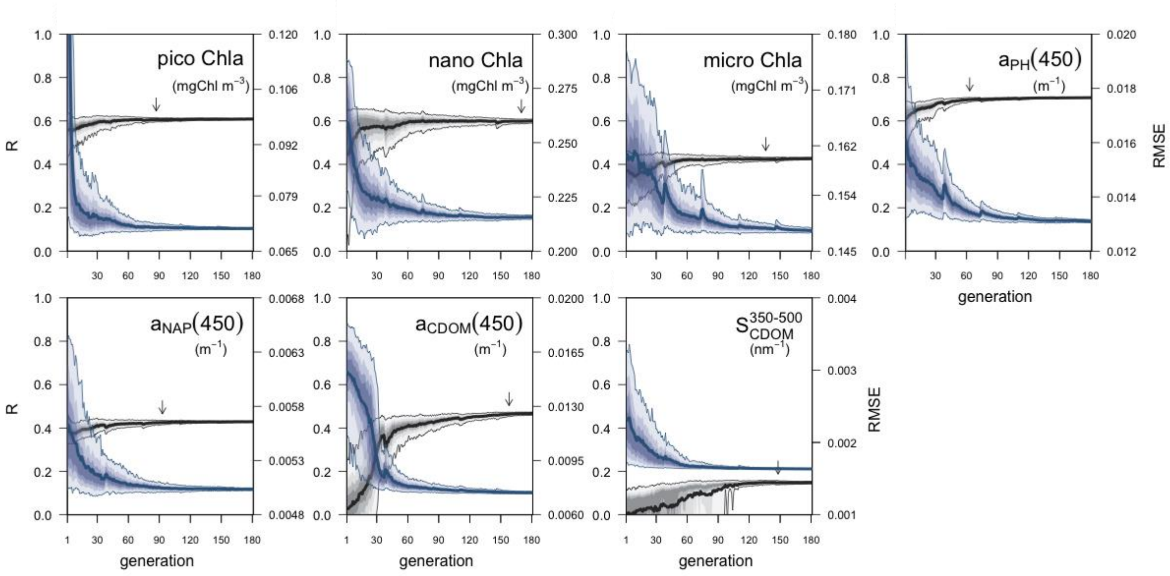
× DYFAMED: Temperature & salinity. Nutrients.



Optimization of parameter values

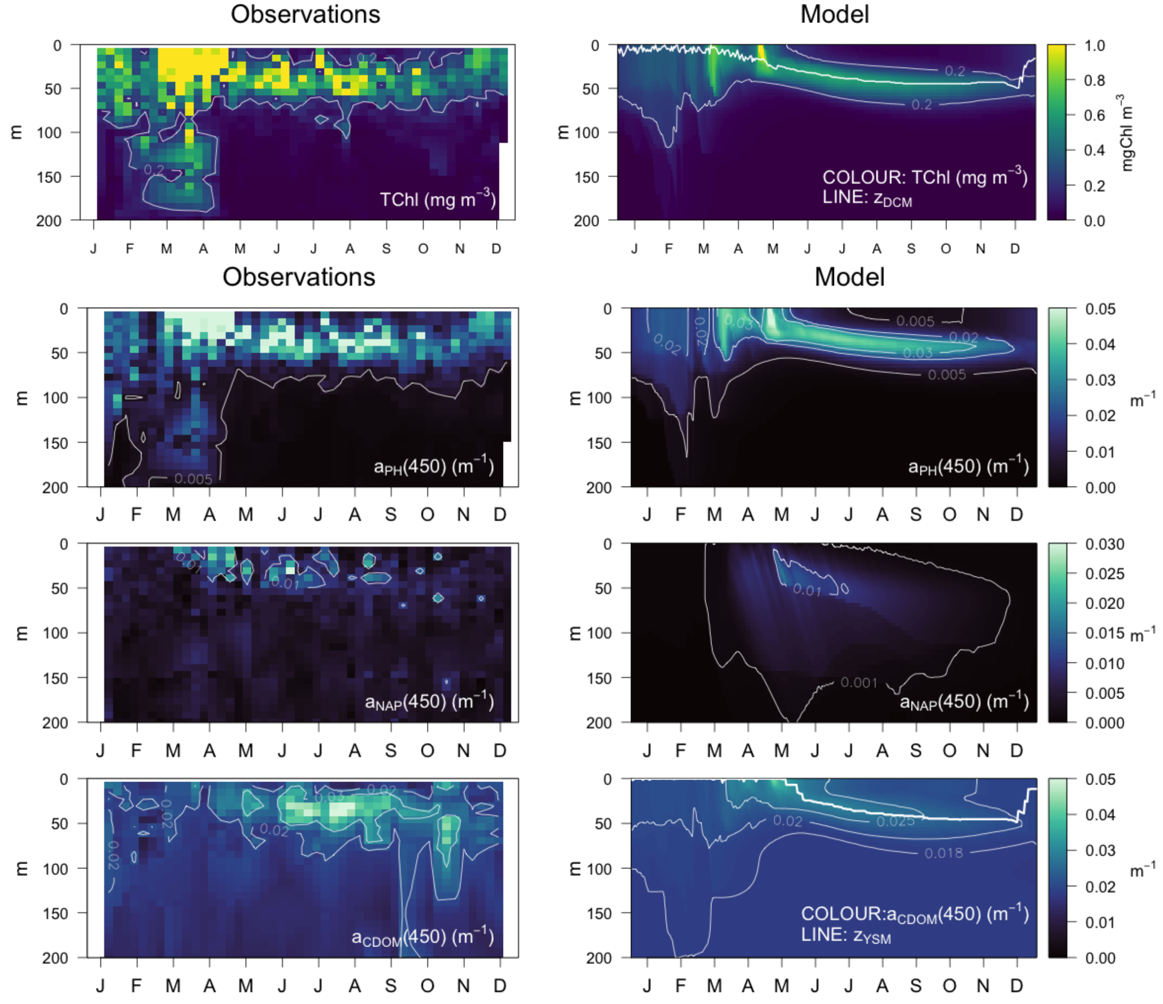
- **ParSAC auto-calibration tool**: genetic algorithm (Differential Evolution), Bruggeman & Bolding (2020) ParSAC 0.5.7

- **Observations:**
  - Pico-, Nano- and Micro-chlorophyll
  - a_{PH} @ 450 nm, a_{NAP} @ 450 nm, a_{CDOM} @ 450 nm
  - CDOM spectral slope between 350-500 nm



DE algorithm minimized misfit model-observations (2009-2014, 2 years spinup) in ~140 generations.

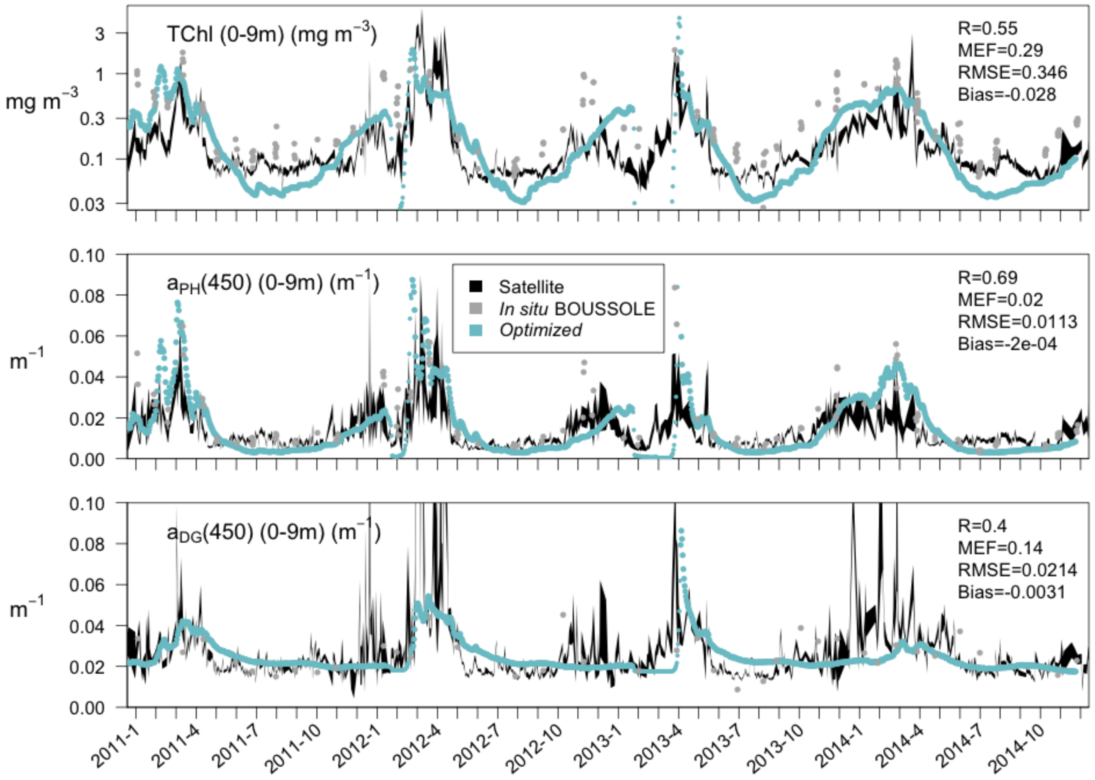
Observed TChl-a and IOPs: $a_{PH}(450)$, $a_{NAP}(450)$ & $a_{CDOM}(450)$



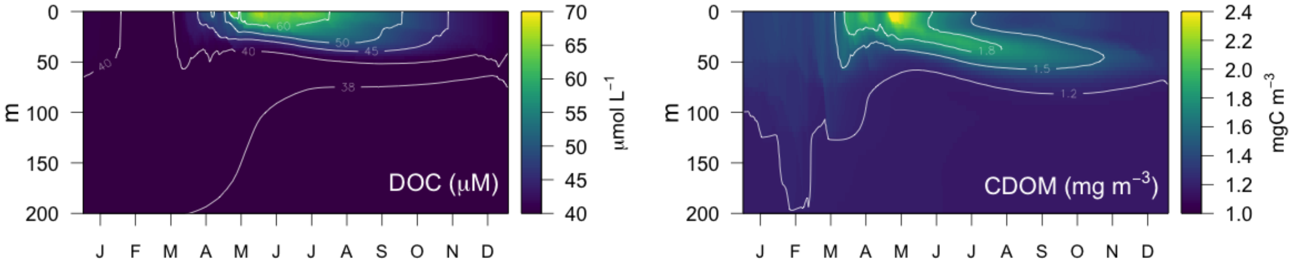
Validation with observed and non-observed variables

- Model output reproduced remote observations (TChla, $a_{PH}(443)$ & $a_{DG}(443)$) and *in situ* observations of light absorption budget and bio-optical relationships.

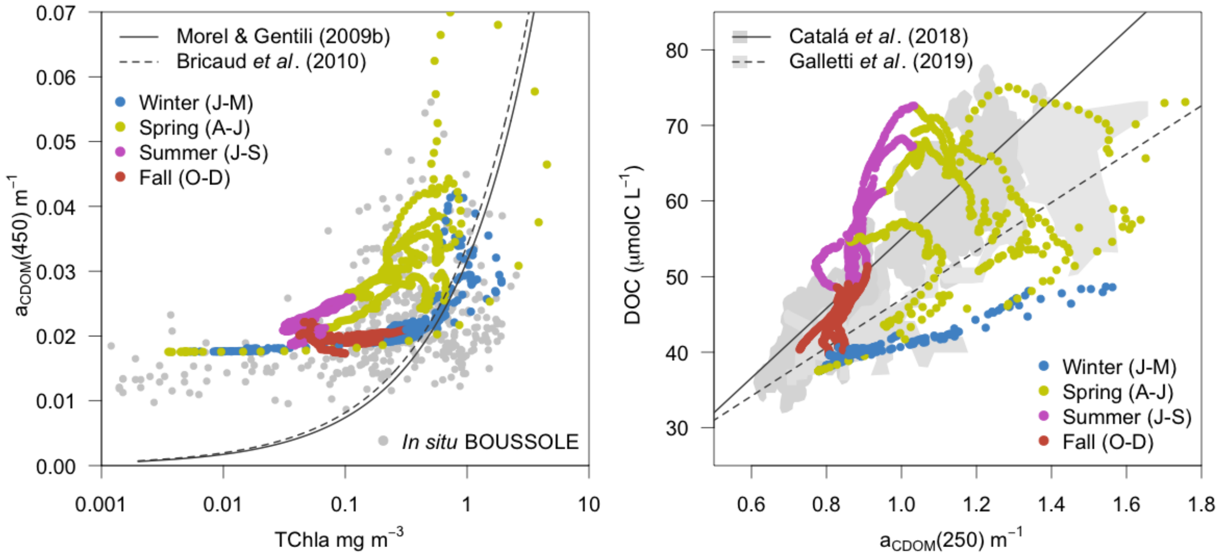
Remote-sensing products (CMEMS):



Non-observed biogeochemical products:



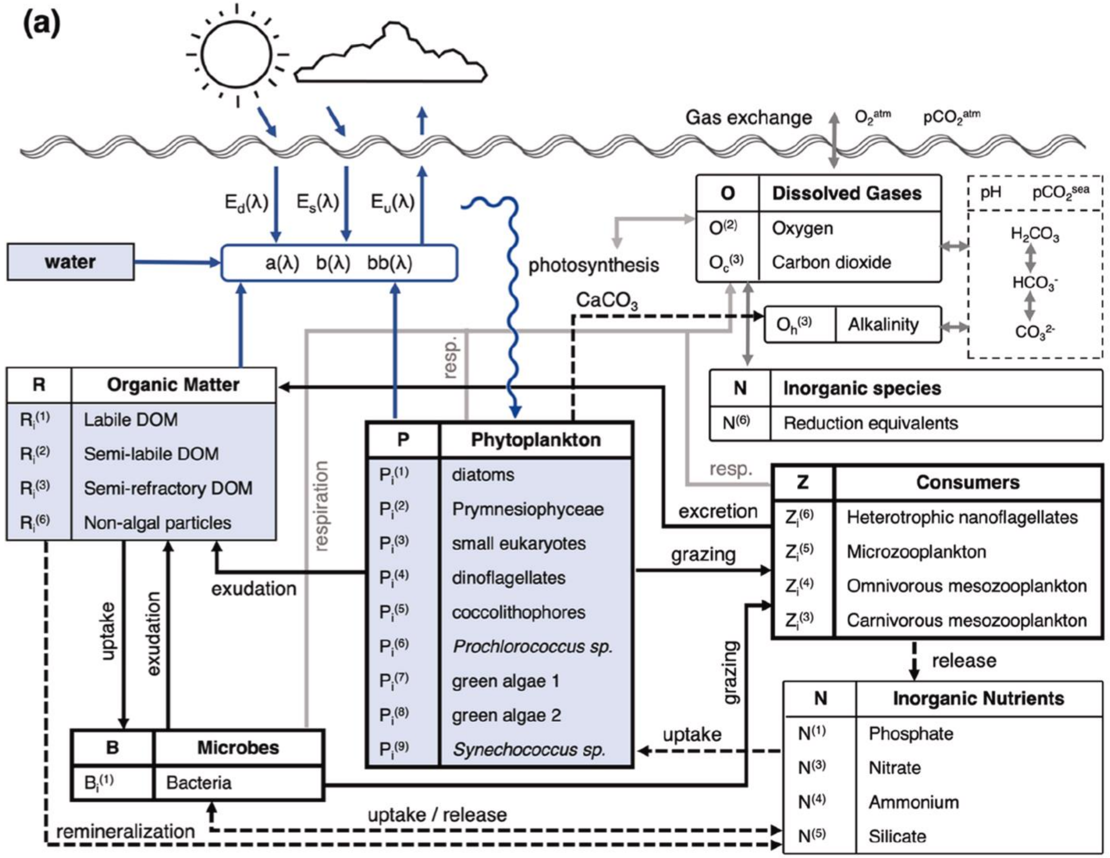
Bio-optical relationships:

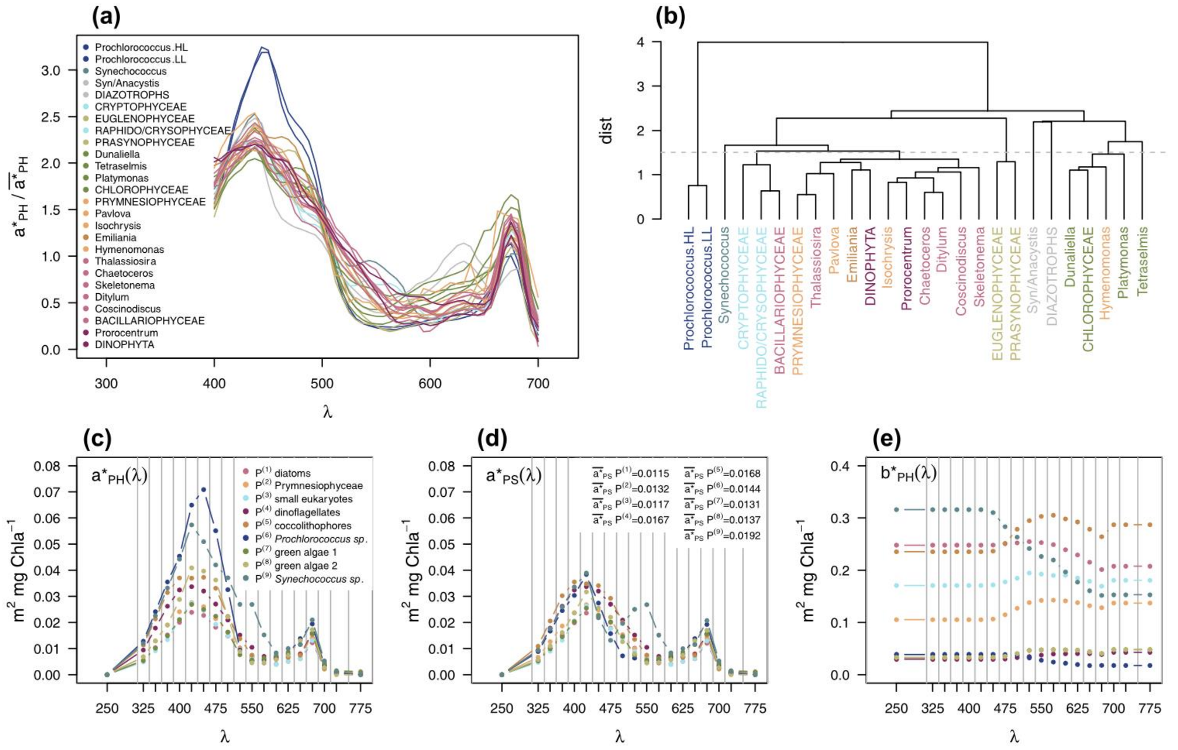


Álvarez et al. in review

Future perspectives – PFT bio-optical properties

NECCTON

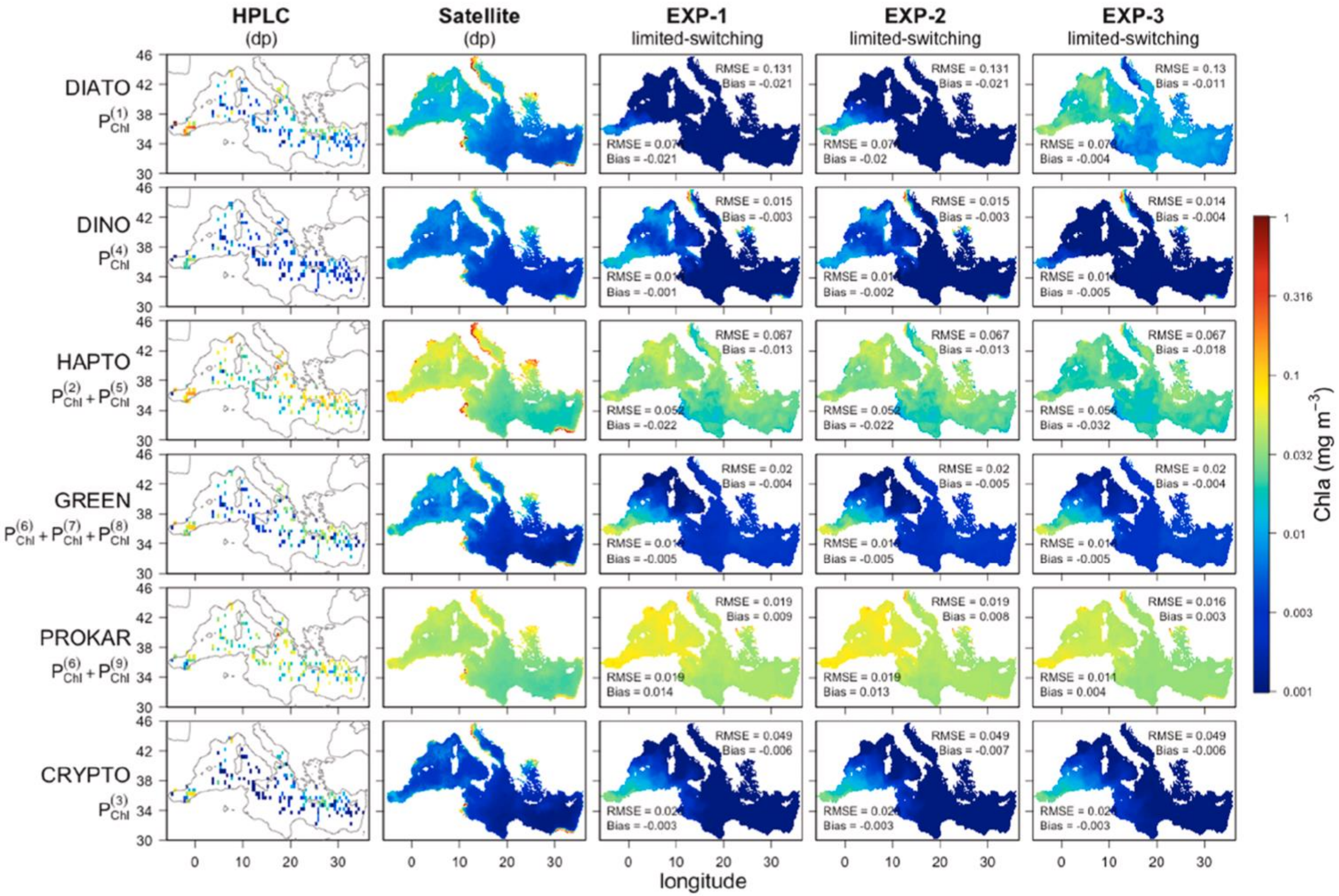




Álvarez et al., 2021

Future perspectives – PFT bio-optical properties

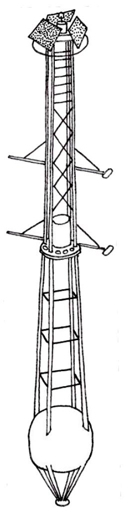
NECCTON

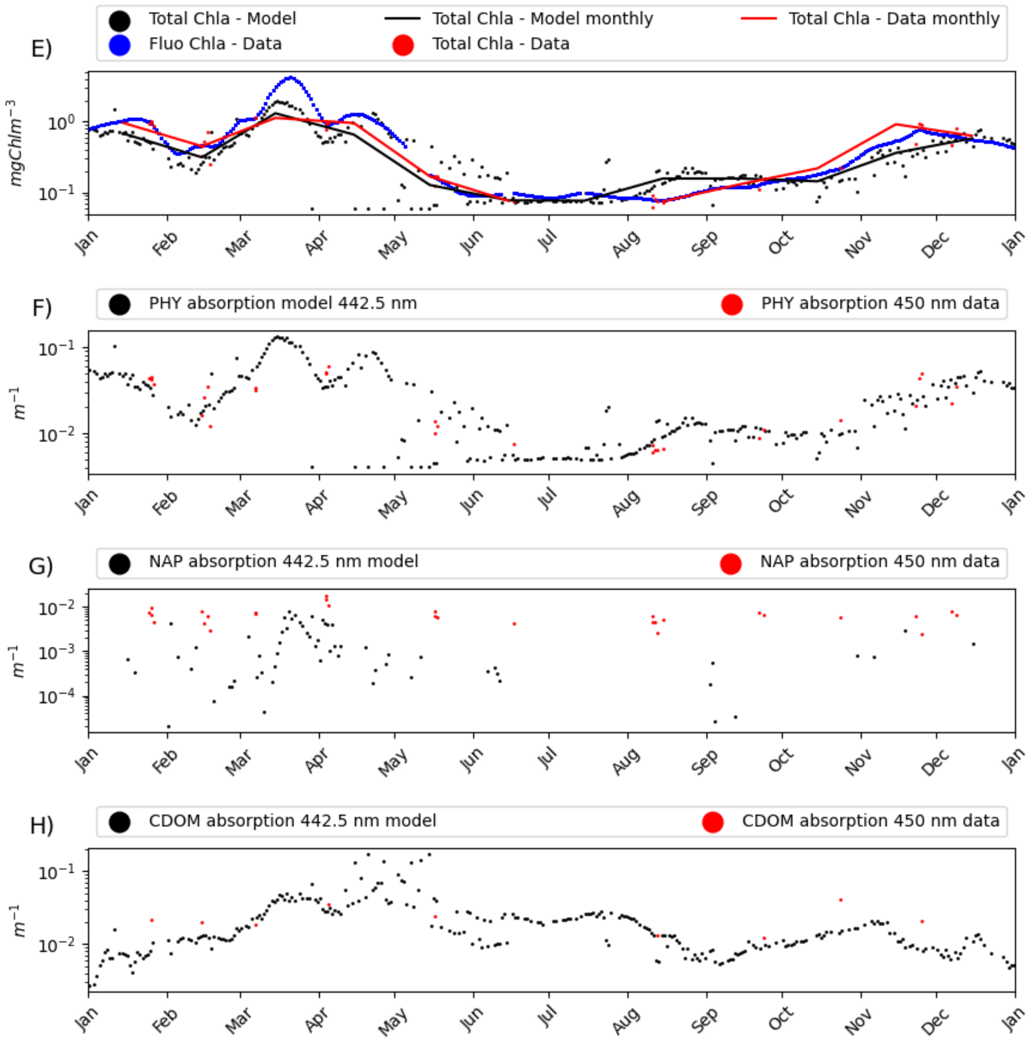


Álvarez et al., 2021

Future perspectives – Rrs assimilation

$$\frac{dE_d}{dz} = -\frac{a+b}{\cos\theta_d}E_d$$
$$\frac{dE_s}{dz} = -\frac{a+r_s b_b}{\overline{v}_s}E_s + \frac{r_u b_b}{\overline{v}_u}E_u + \frac{b-r_d b_b}{\cos\theta_d}E_d$$
$$-\frac{dE_u}{dz} = -\frac{a+r_u b_b}{\overline{v}_u}E_u + \frac{r_s b_b}{\overline{v}_s}E_s + \frac{r_d b_b}{\cos\theta_d}E_d$$





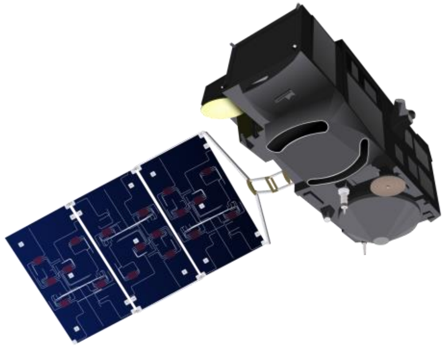
- ▶ Inversion model based on forward model

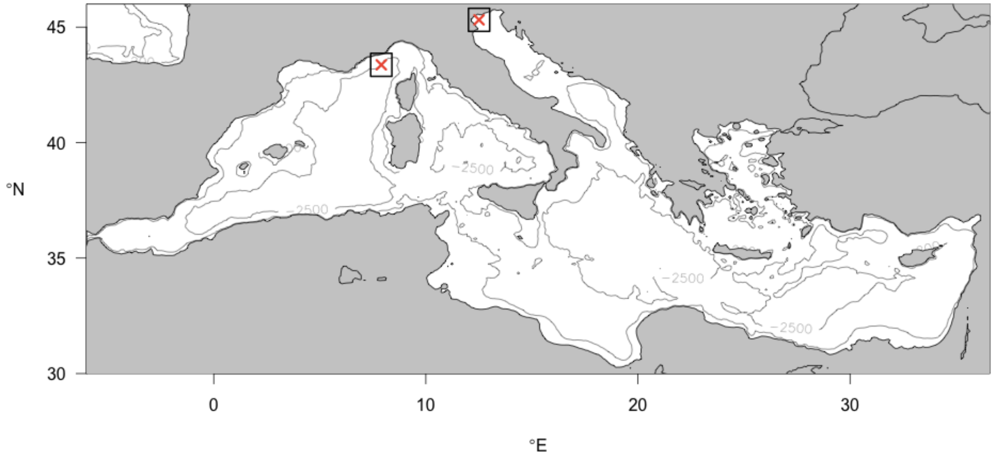
Lazzari et al., in prep

NECCTON → Assimilation of new types of observations

Rrs from SENTINEL 3A OLCI

Nr. of Band	Center Wavelength (nm)	Bandwidth (nm)
1	412.5	15
2	442.5	10
3	490	10
4	510	10
5	560	10
6	620	10
7	665	10
8	673.75	7.5
9	681.25	7.5





Rrs from PRISMA

Parameter	VNIR channel	SWIR channel
Spectral range	400-1010 nm	920-2505 nm
Spectral resolution (FWHM)	≤ 12 nm	≤ 12 nm
Spectral bands	66	171

D.A. SCHEMES

3D VAR [OGS]

NEW DEVELOPMENTS

OBSERVATION OPERATOR based on Inversion model and Neural Network [OGS]

Thank you for your attention