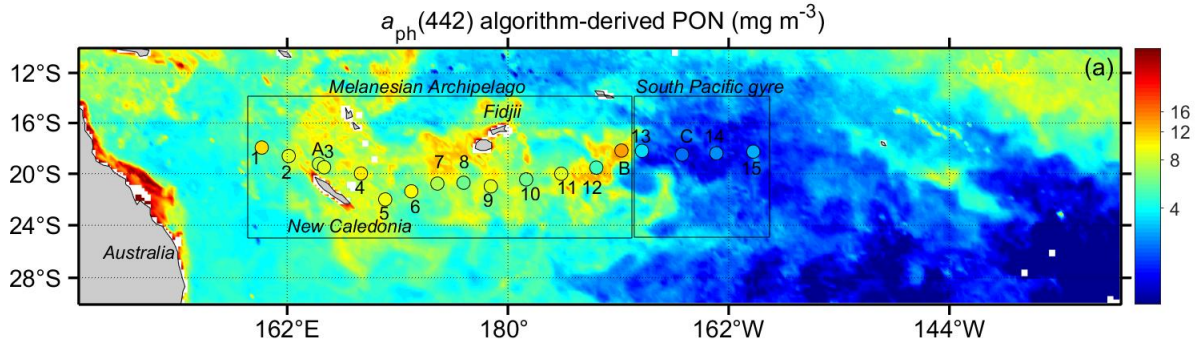
How to monitor the Ocean With SATELLITE observations?

Marine BioGeochemistry

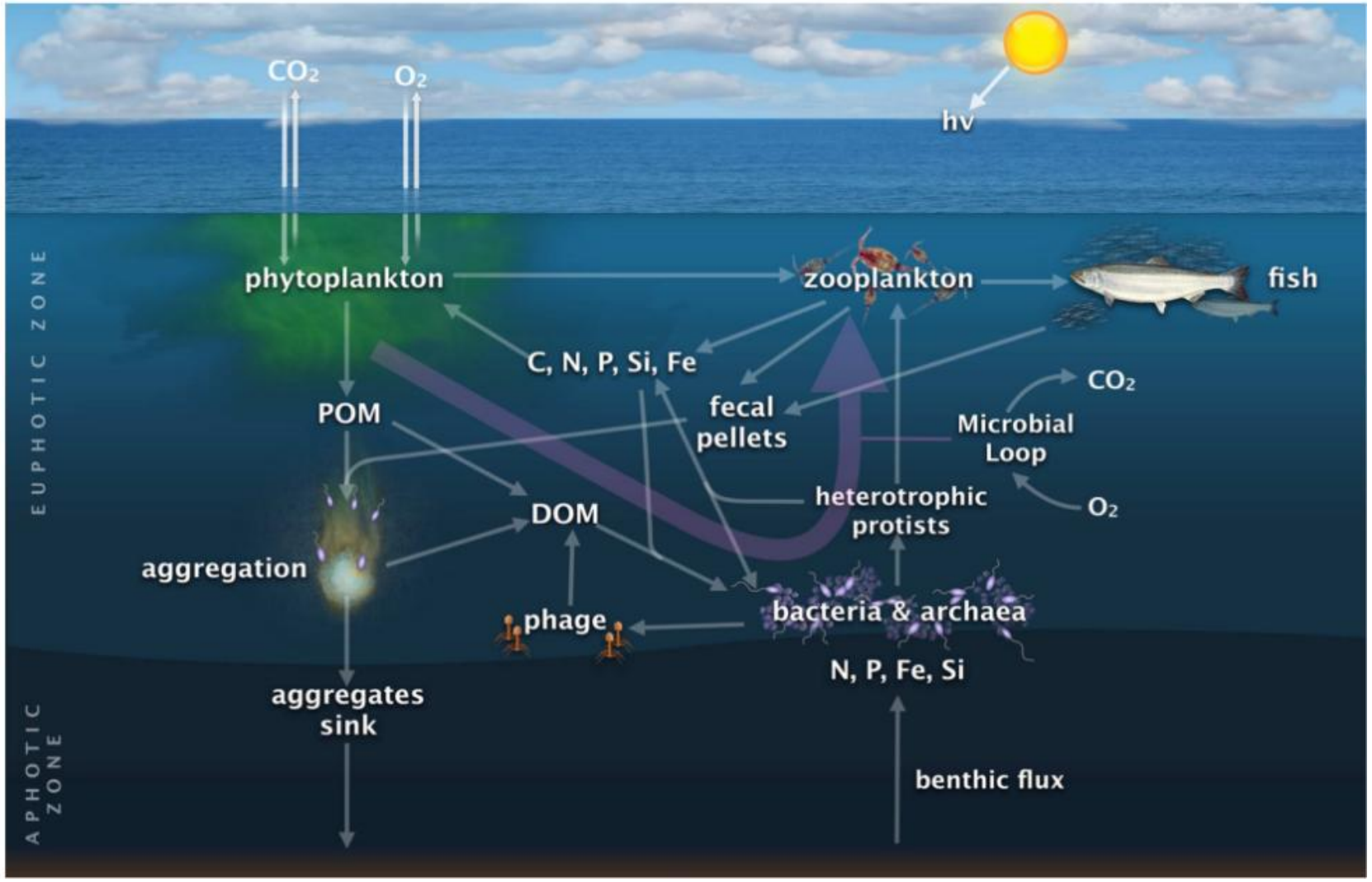
One Ocean Science Congress 2025

Hubert Loisel

Alain Fumenia, Roy El Hourany , Vincent Vantrepotte, Daniel S.F. Jorge, Marie Monterro, Lucile Duforêt, Marine Bretagnon, Philippe Bryère, Antoine Mangin, and many others

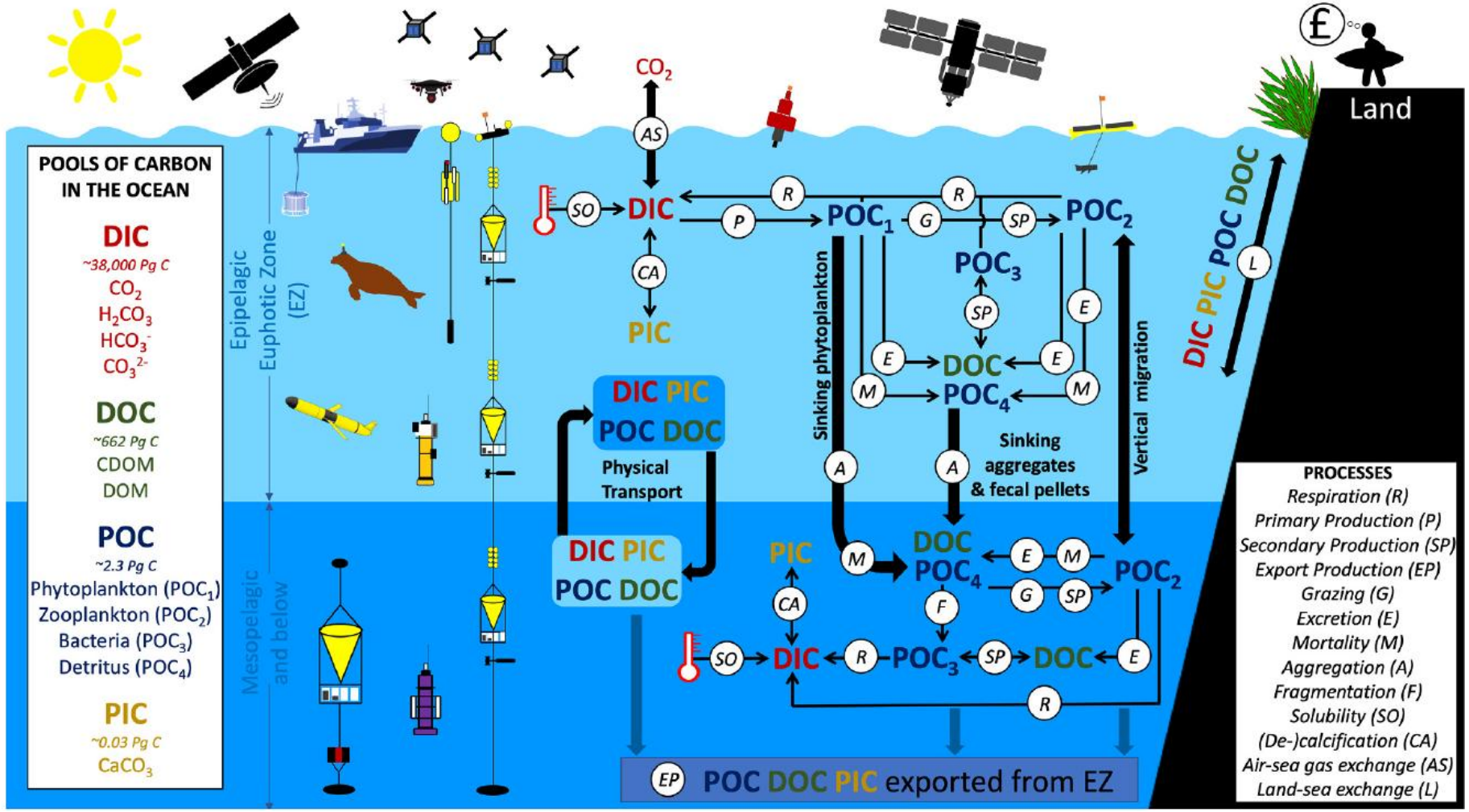


Marine biogeochemistry deals with the exchange and distribution of chemical elements and compounds among various living and non-living entities within the ocean, as well as between the ocean, atmosphere and land.



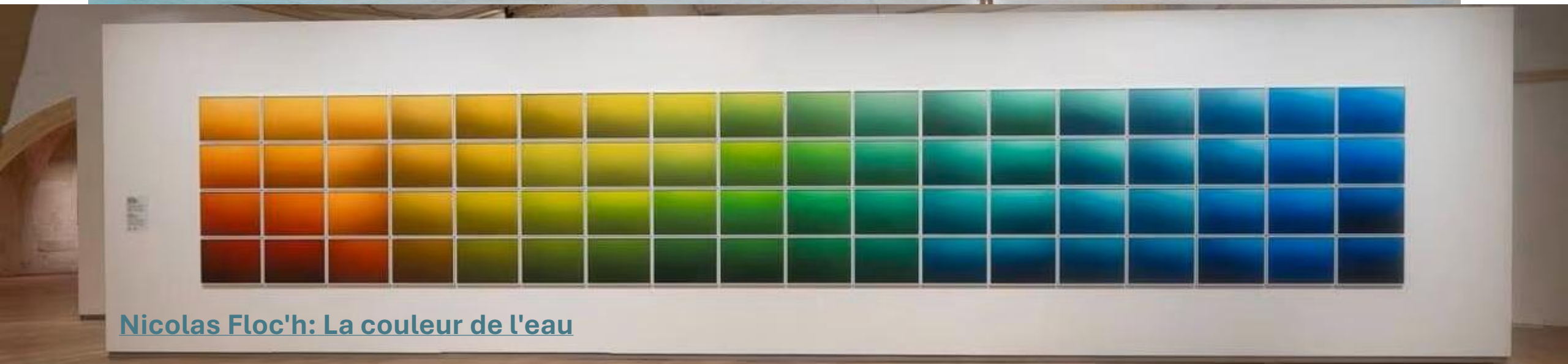
Global view of the pelagic food web. (*Worden et al., 2015*).

Tightly linked to the other element cycles, the **carbon element** is at the center of broad research activities due to its central role in **climate regulation** (i.e. *biological pump*) **and life** (i.e. *marine food web*) on earth.



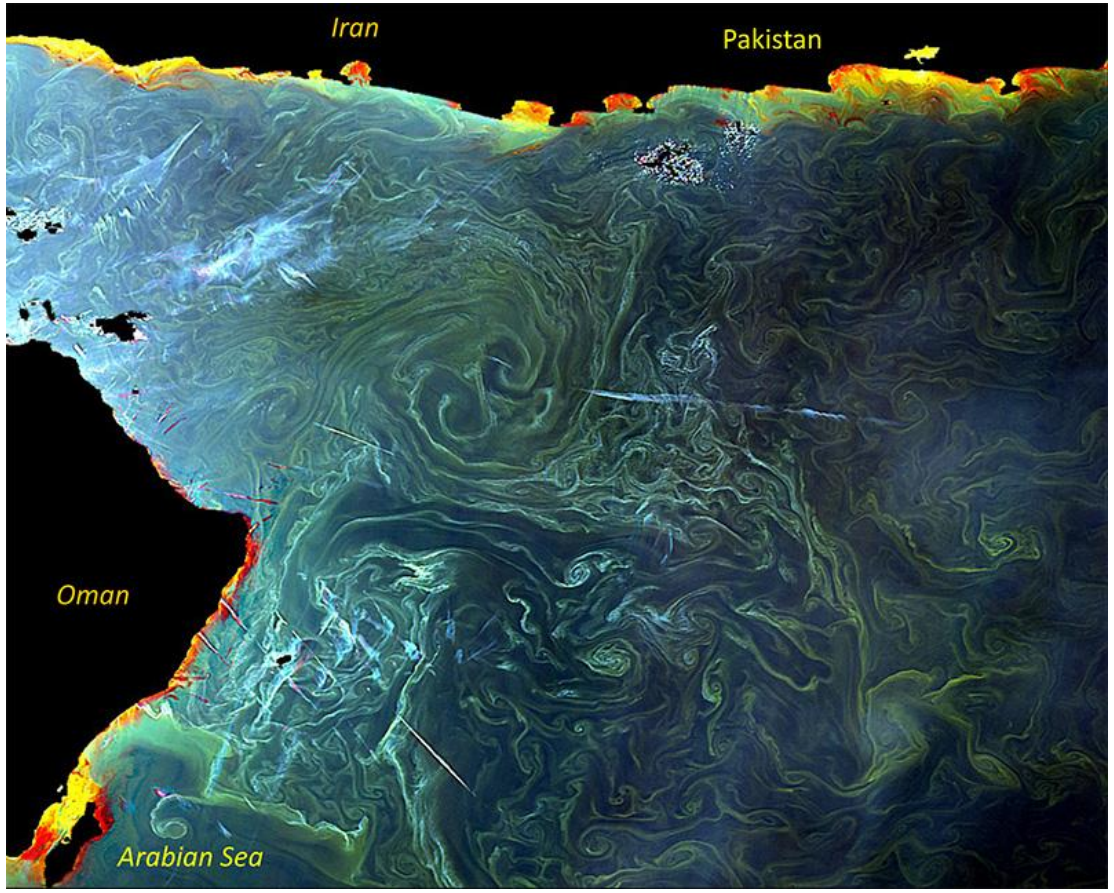
Remote sensing of the biological carbon pump. *Brewin et al.*, (2021)

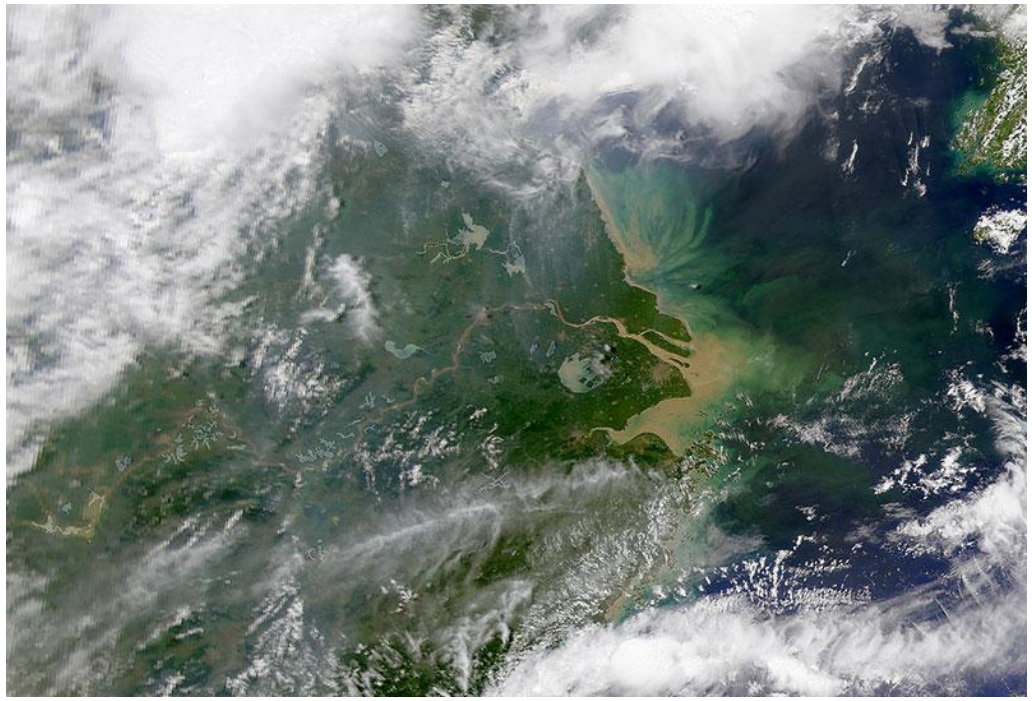
The great variety of colors encountered in the water masses witnesses the richness of its biogeochemical composition

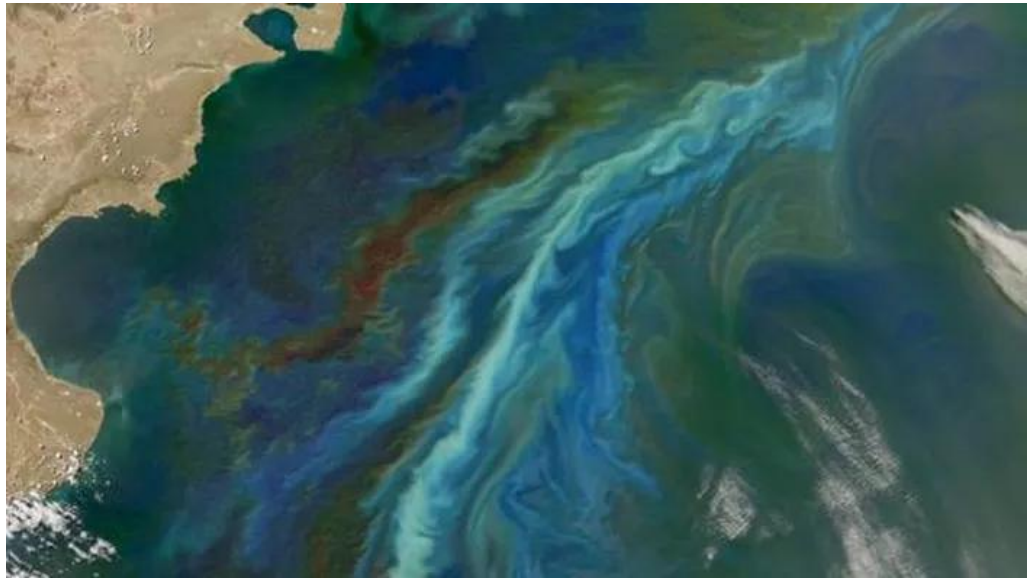


Nicolas Floc'h: La couleur de l'eau

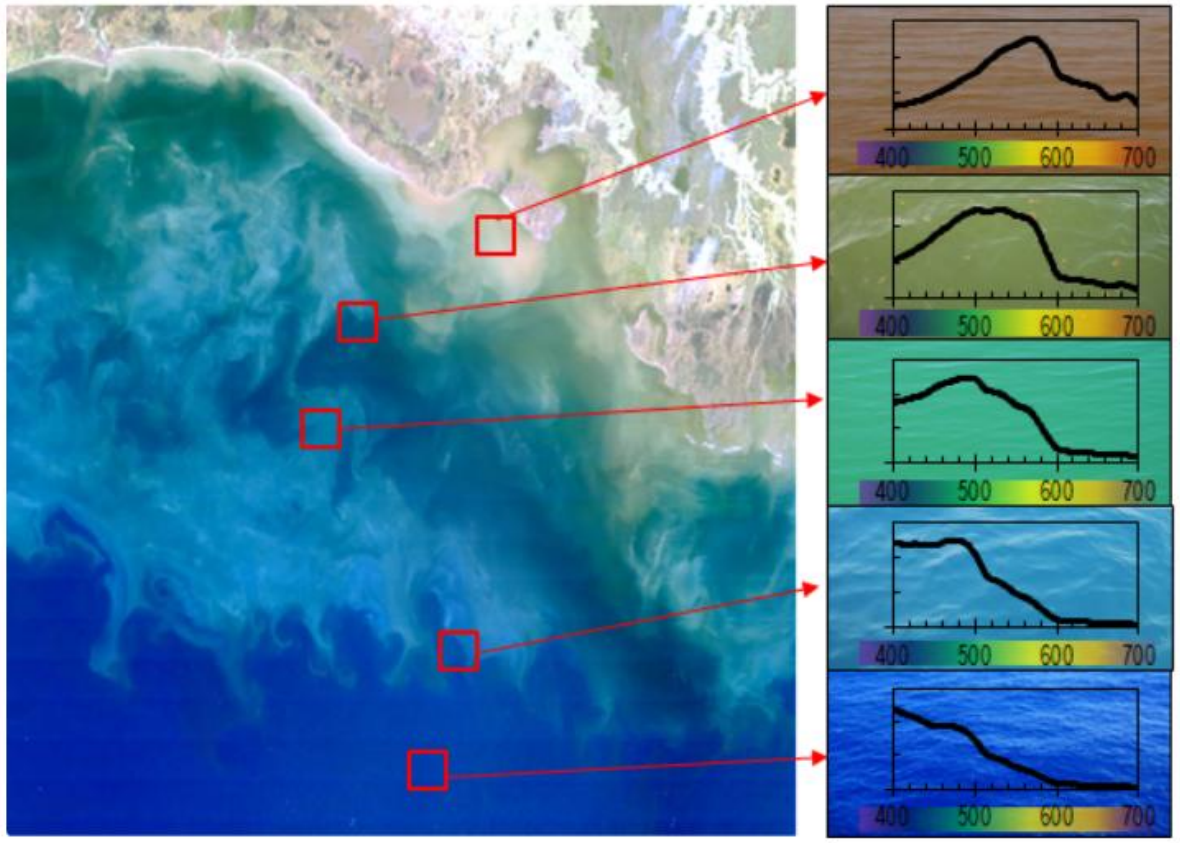
Images of satellite ocean color observations reveal by themselves a complex and highly heterogeneous medium emphasizing the tight coupling between physical and biogeochemical processes in the ocean.





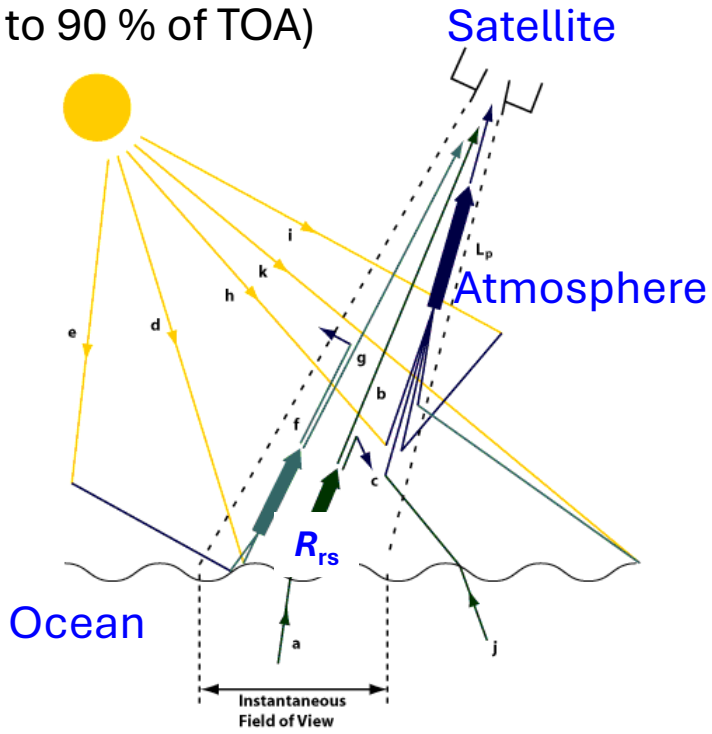


Ocean Colour Radiometry, is defined as the spectral variations of the water leaving signal in the visible part of the spectrum and is generally quantified by the spectral remote sensing reflectance, $R_{rs}(\lambda)$



From: Jeremy Werdell, NASA

$\boldsymbol{R_{rs}(\lambda)}$ is estimated from the Top Of Atmosphere (TOA) signal measured in space and corrected from atmospheric effects (80 to 90 % of TOA)



Ocean Color Radiometry, considered now as an **Essential Climate Variable,** brings key **qualitative and quantitative information** on aquatic biogeochemical elements thanks to the application of **bio-optical algorithms.**

TOA signal

Atmospheric corrections

$R_{rs}(\lambda)$

Bio-optical algorithms

First quantitative assessments and first global estimations **of some biogeochemical elements from space**

Chl-a (in 1981) and global in 1986

PIC (in 1983) and global in 1994

POC (in 1999) and global in 2002

Phytoplankton groups (early 2000) and global in 2005

DOC (early 2000) and global in 2022

PON since 2023 at global scale

and others such as primary production, and CO_2 fluxes

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To better address the strong bio-optical complexity from coastal to open ocean waters, the Optical Water Class approach has recently been developed to decrease the uncertainty on the biogeochemical product retrieval.

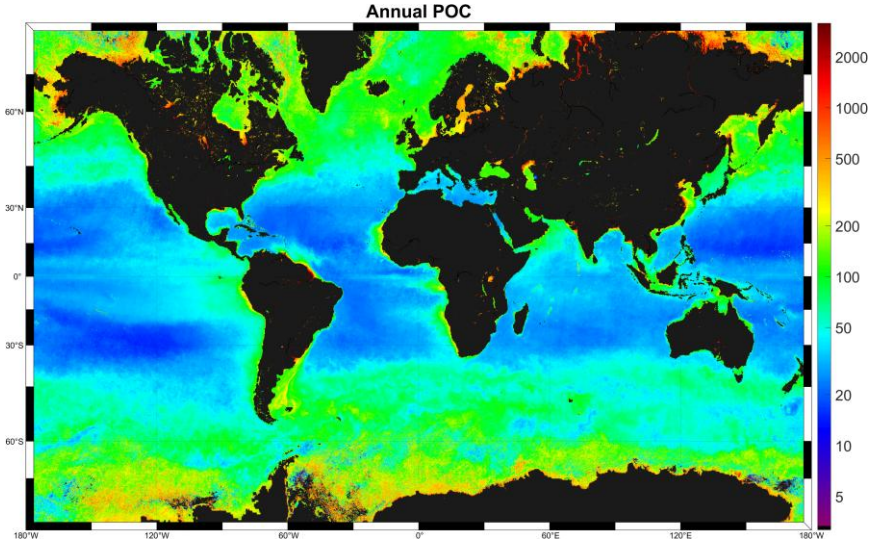
$$POC = P_1\, POC_1 + P_2\, POC_2 + P_3\, POC_3$$

Where P_i are the belonging probabilities of a pixel to a OWC

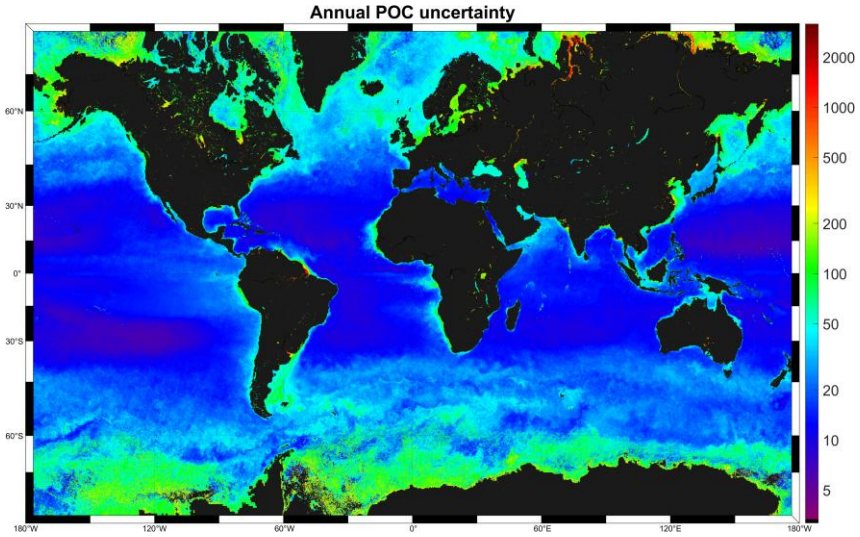
POC_3 : from Loisel et al. (2002) and Loisel et al. (2018) for open waters.
POC_2 : from Tran et al. (2016) eutrophic and coastal waters
POC_1 from Le et al. (2016) for very turbid/sediment dominated waters

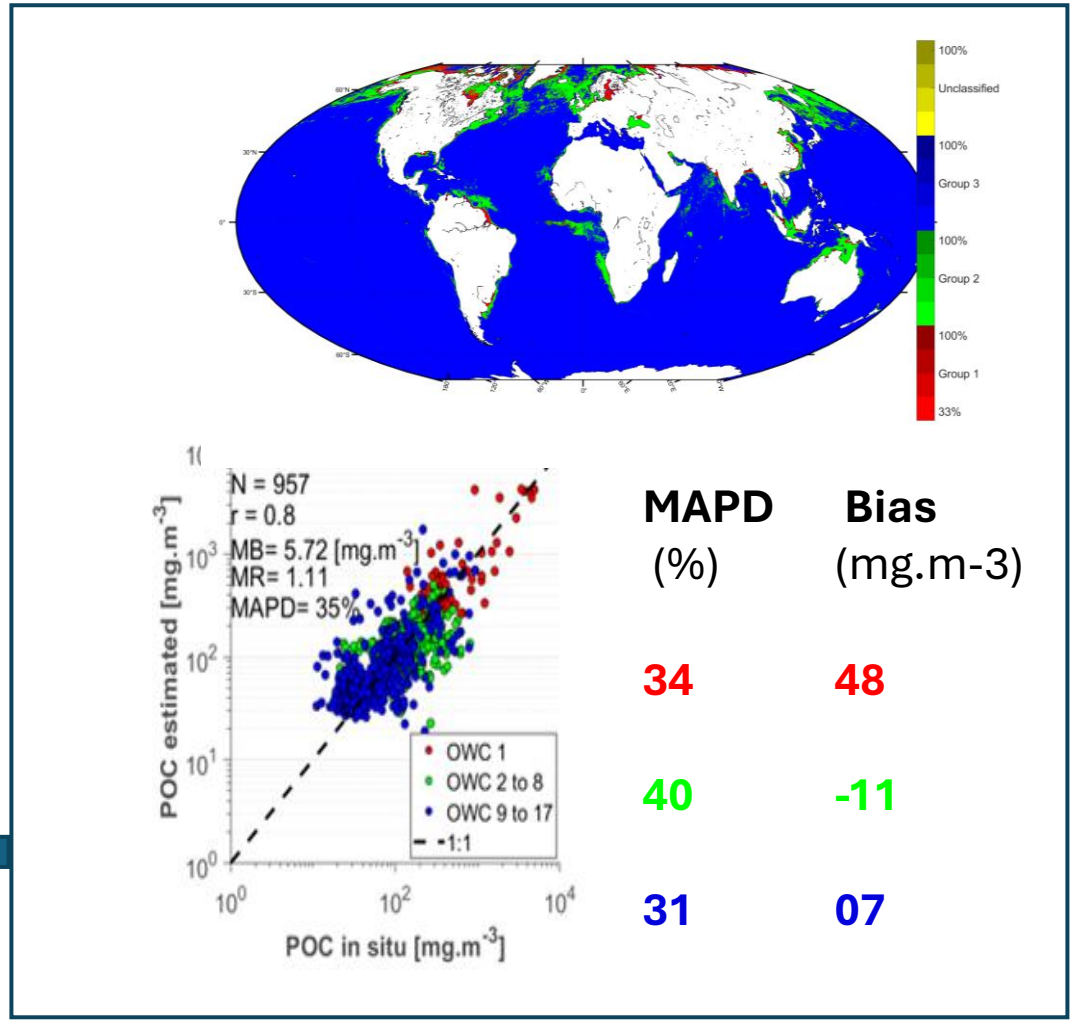
This **OWC approach**, coupled with intensive validation exercises, allow a better assessment of **the per-pixel uncertainty** on the retrieved product (here **POC**).

POC value



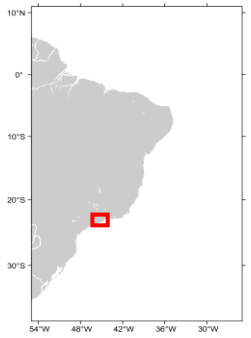
POC uncertainty

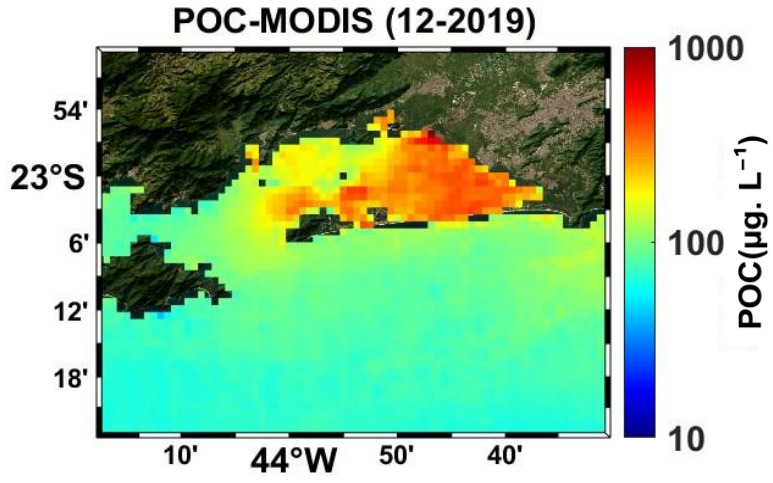


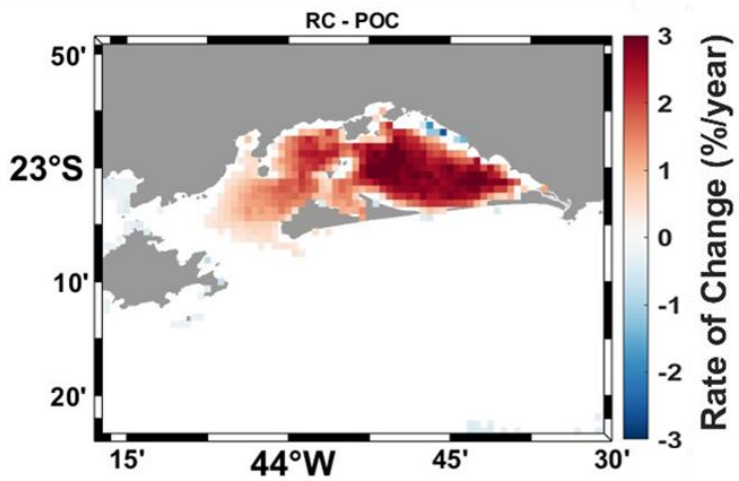


	MAPD (%)	Bias (mg.m-3)
	34	48
	40	-11
	31	07

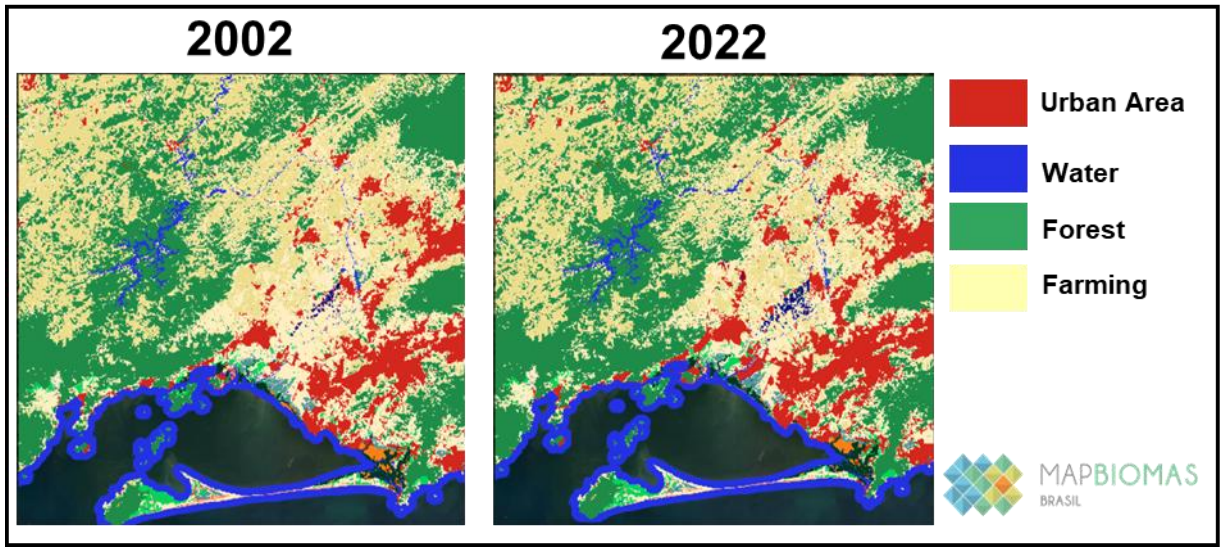
Long time series of OCR products allow to **identify areas impacted by human activities**, such as the recent increase in urbanization in Rio de Janeiro which has significantly altered the biogeochemical quality of Sepetiba Bay

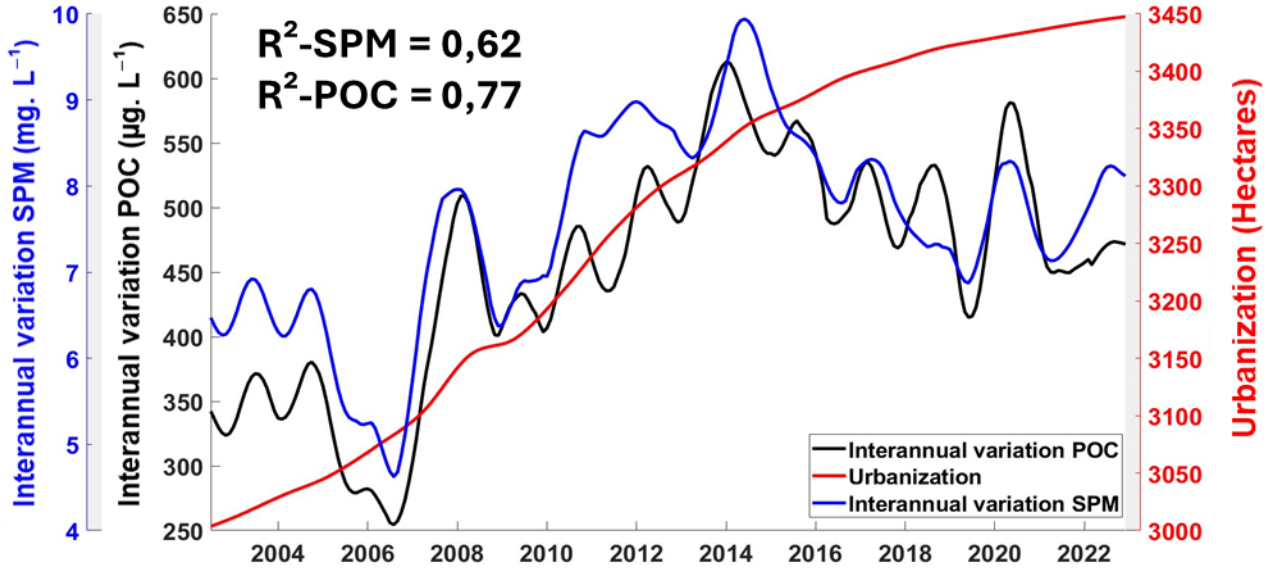






SPM is increasing (45%)
POC is increasing (70%)





The strong decoupling between the source and sink of both *DOC* and its optical component, $a_{cdom}(\lambda)$, as well as their very different ranges of variation *([45-85] mmol.l^{-1} for DOC and 3 orders of magnitude for $a_{cdom}(\lambda)$)* have long limited the number of studies focusing on the remote sensing of *DOC* concentration over open waters.

PhD of Ana Gabriela Bonelli at LOG (CNES/ACRI)
***CNES/TOSCA DOC project** (PI. H. Loisel)*

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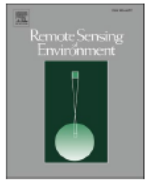

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A new method to estimate the dissolved organic carbon concentration from remote sensing in the global open ocean

Ana Gabriela Bonelli [a,*], Hubert Loisel [a], Daniel S.F. Jorge [a], Antoine Mangin [b], Odile Fanton d'Andon [b], Vincent Vantrepotte [a]

***ESA BICEP project** (PI. S. Sathyendranath)*

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A machine learning model-based satellite data record of dissolved organic carbon concentration in surface waters of the global open ocean

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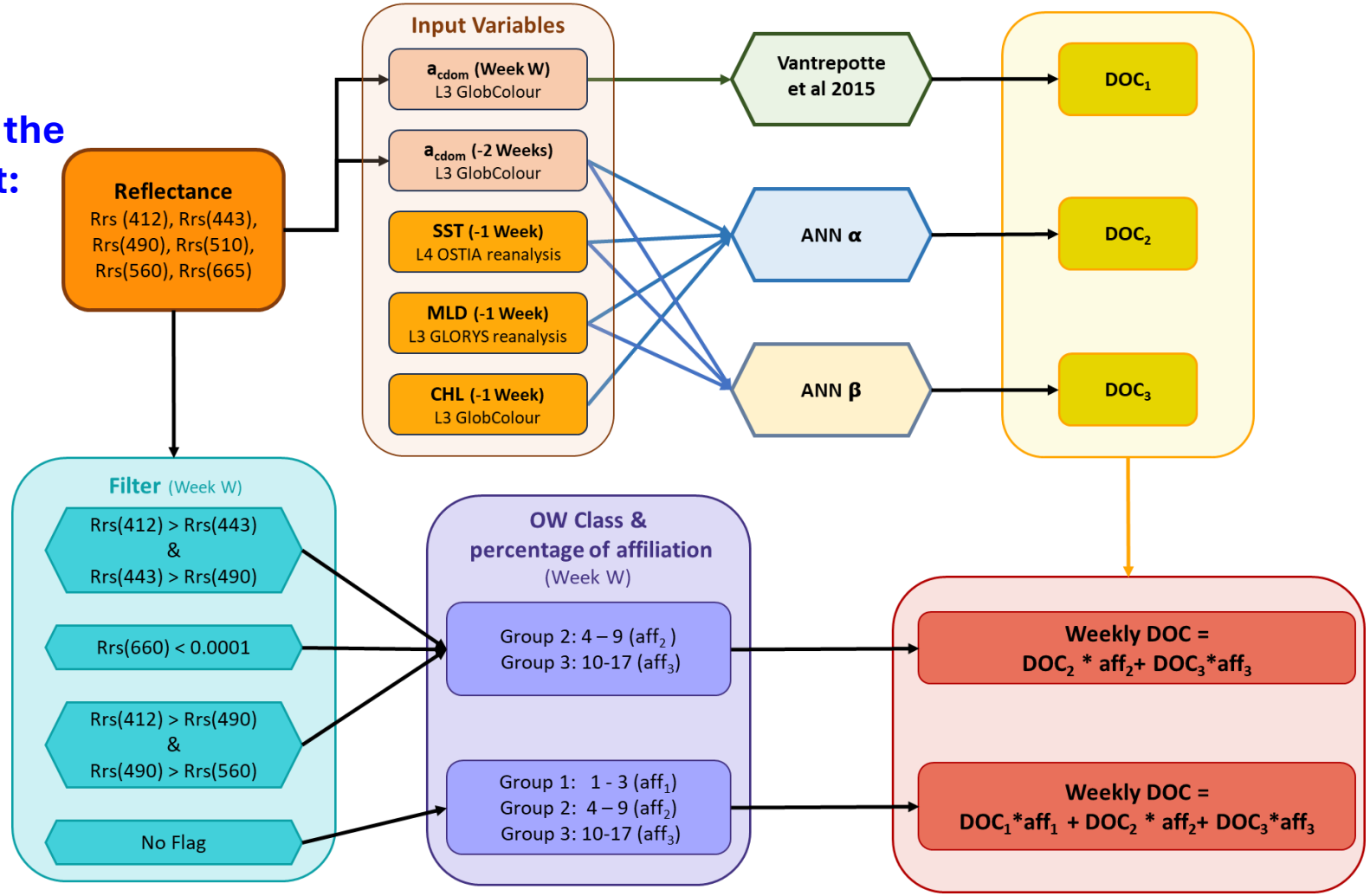
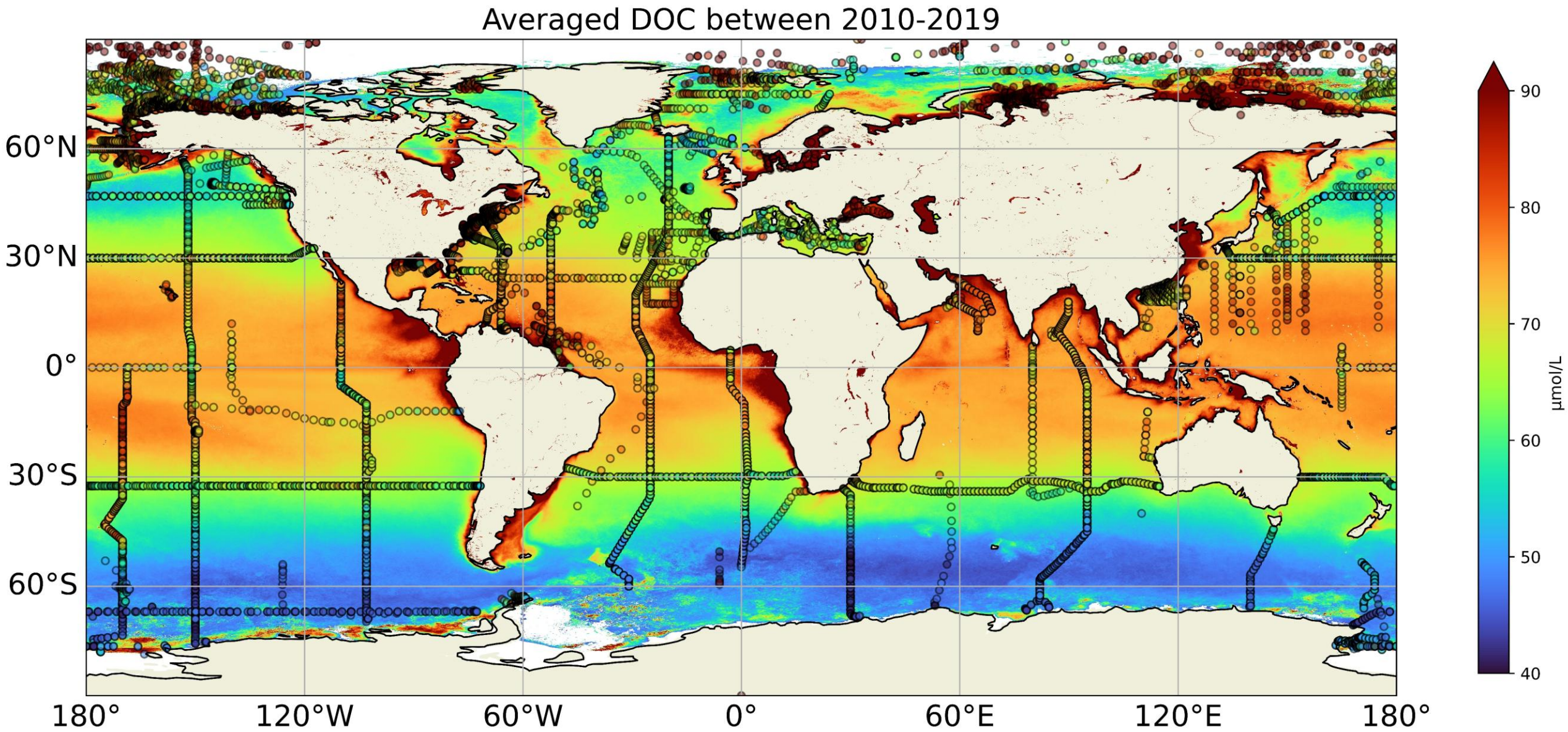
The DOC algorithm of Bonelli et al. (2022) combines physical (MLD, SST) and bio-optical (*Chla*, $a_{cdom}(\lambda)$) information with a lag of one or two weeks, allowing to account for the delay between carbon fixation and CDOM production, through microbial and abiotic processing of phytoplankton carbon fixation.

The new DOC algorithm generated in the frame of OCROC Mercator-Int project:

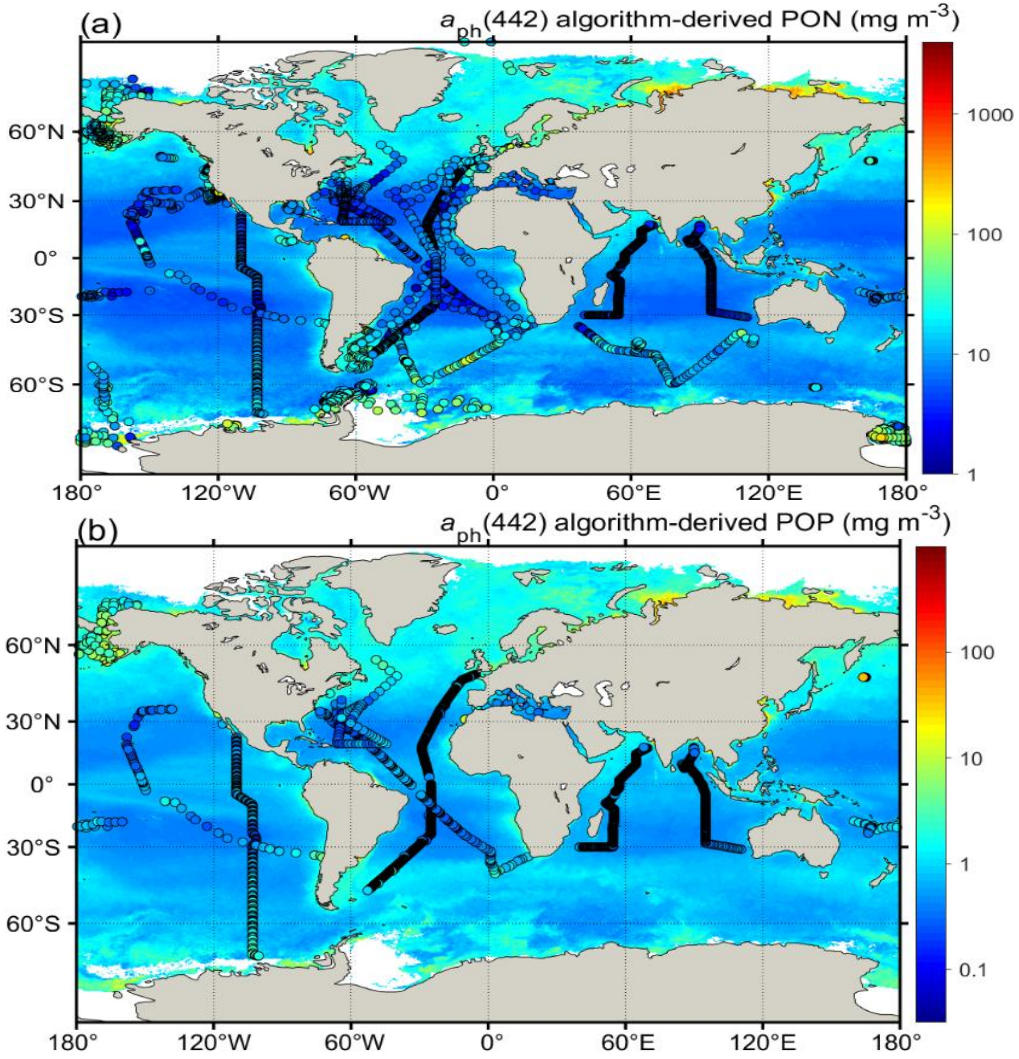




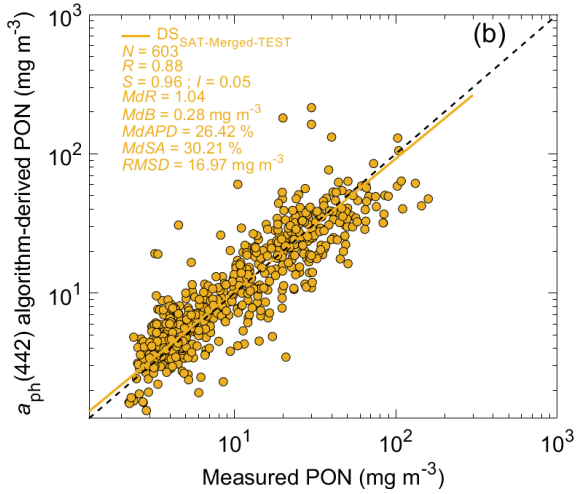
See poster N° P720 by Montero et al.

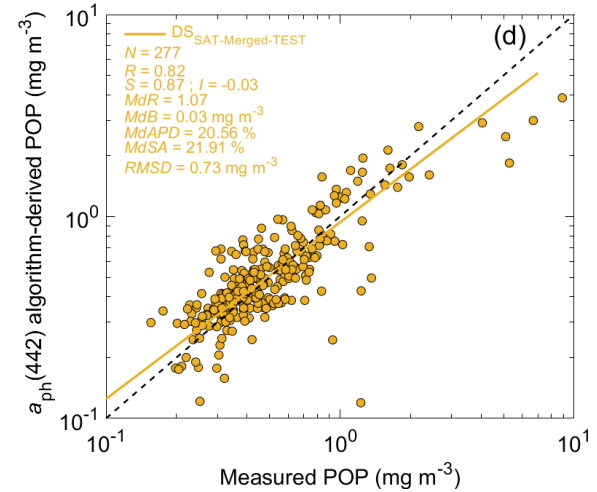
Recent studies demonstrate that both **PON** and **POP** can be estimated opening new avenues towards our better comprehension of the marine biogeochemical cycles (i.e. Redfield ratio)

CNES/TOSCA projet COUL-PNP



Validation





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How to monitor the Ocean?

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