# CNES
# EARTH OBSERVATION PROGRAM
## FOCUS ON OCEAN COLOUR

Aurelien
**CARBONNIERE**
Coastal Zones & Marine Cryosphere
Program Manager
Strategy Directorate

**International Ocean Color Science**
**2025 Meeting**
**December 3, 2025**

# CNES

## OUR 4 STRATEGIC PRIORITIES

© CNES/ESA/Arianespace/CSG Photo & Video Dept./S Martin, 2023

**STRENGTHEN**
our strategic independence

© CNES/Thierry De Prada, 2022

**SUSTAIN**
a competitive space ecosystem

© CNES/Distribution Airbus DS, 2020

**WORK**
towards a sustainable world

© CNES/Emmanuel Grimault, 2021

**EXTEND**
our scientific excellence

RÉPUBLIQUE FRANÇAISE
*Liberté Égalité Fraternité*

cnes

# SCIENCE AND SOCIETY

**Scientific and societal challenges are strongly linked to global change and environmental issues**

## Keep studying and understanding the Earth System

- Understand the Earth system and the processes that control it
- Predict the evolution of our planet
- Understand human impact

## . . . to live better

- Predict our environment in the coming days/weeks
- Predict and manage extreme events
- Understand and manage our needs for water and food


**A universal need : to study and understand processes on large spatio-temporal scales, in all compartments of the Earth system.**

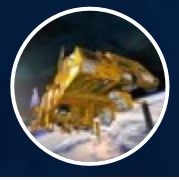
RÉPUBLIQUE FRANÇAISE
*Liberté Égalité Fraternité*

cnes

# MISSIONS IN EXPLOITATION AT CNES

## (AS OF DEC 2025)

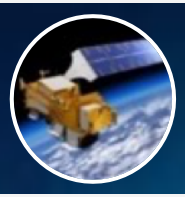
### Infrared sounding



IASI 2/Metop B - 2012

IASI-NG/Metop SG A1 - 2025

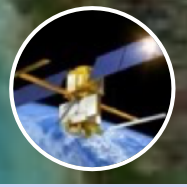
Aug. 12, 2025



IASI 3/Metop C - 2018

### Ocean & Hydrology

SMOS - 2009



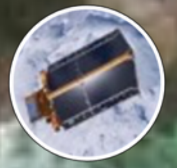
SWOT - 2022

### Satellite altimetry

Hy-2 B/C/D

Jason 3 - 2016


Sentinel-6 A& B

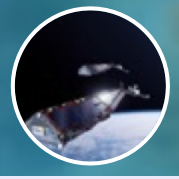


Cryosat-2 - 2010

CFOSAT - 2018

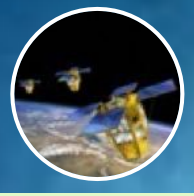
Sentinel-3A - 2016

### Magnetic field

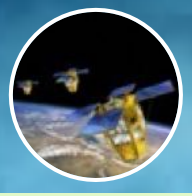


Swarm - 2013

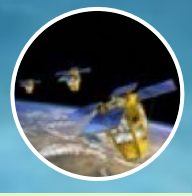
### Defence / Optical imagery



CSO 1 - 2018

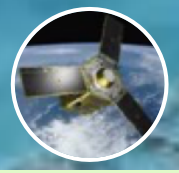


CSO 2 - 2020

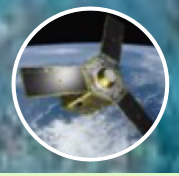


CSO 3 - 2025

### Optical imagery

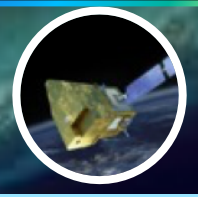


Pléiades 1 A - 2011



Pléiades 1 B - 2012

### Carbon



MicroCarb - 2025

July 25, 2025

Saral-AltiKa 2013

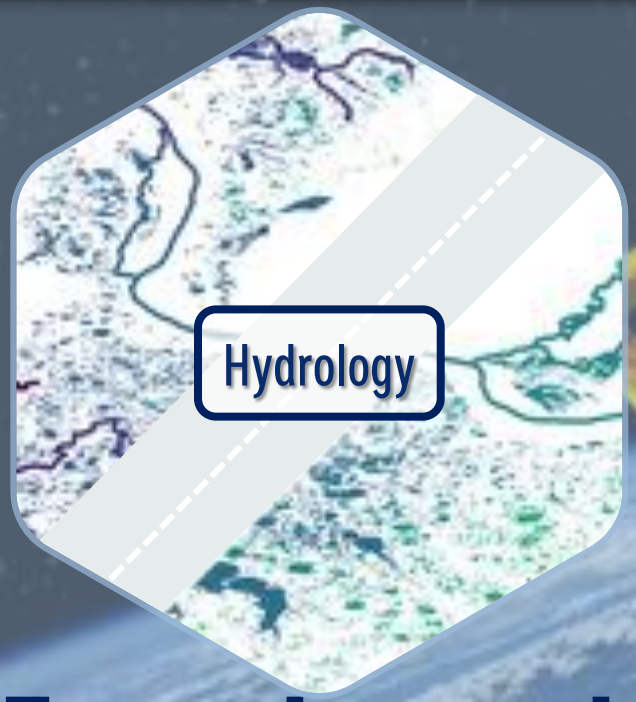
Sentinel-3B - 2018

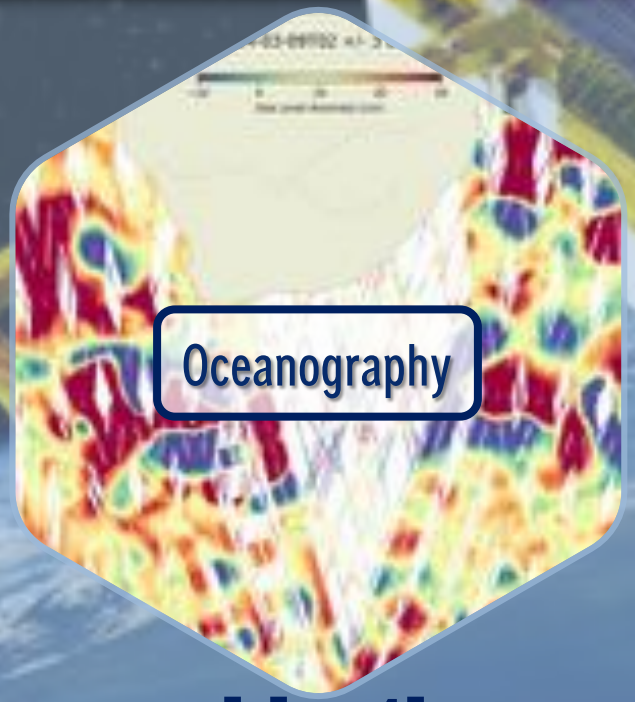
RÉPUBLIQUE FRANÇAISE
*Liberté*
*Égalité*
*Fraternité*

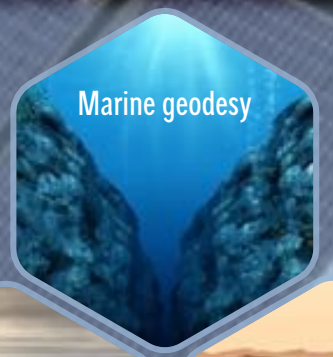
cnes

# CNES MISSIONS ACHIEVEMENTS

## SWOT, THE REVOLUTION FOR WATER










**From primary science objectives…**

**… To secondary objectives**

**Unexpected findings**

**Unexplored potential**

# OUR FUTURE MISSIONS
## IN DEVELOPMENT

SPS 2024 priorities

**MICROCARB**
Carbon from space

**CO3D**
Global 3D mapping

**IASI-NG**
Atmosphere composition

**TRISHNA**
Surface temperature & Soil moisture

**C3IEL**
Convective clouds & lightning

**MERLIN**
Monitoring methane emissions

**SMASH**
High-revisit hydrology

**GENESIS**
Geodetic references

**ODYSEA**
Ocean currents & winds

**C²OMODO**
Convection, aerosols & climate

**MAGIC/NGGM**
Earth's gravity field

**S3-NG-Topo**
Wide-swath altimetry for ocean & hydrology

**CARIOQA**
Quantum gravimetry

2025 2030 2035

**Our European and international partners**

# OUR COMMITMENT TO THE OCEAN

## The Space4Ocean Alliance

- Strengthen **collaboration** between space sector and marine/maritime stakeholders
- Develop **capacity building** to empower frontline countries
- Share good practices based on relevant **science**
- Support the development of advanced **ocean indicators**
- Support the development of innovative **space missions**
- Promote the delivery of **operational services**


UN OCEAN CONFERENCE NICE 2025 FRANCE

**30 signatories**

gathered at UNOC'25 in Nice

RÉPUBLIQUE FRANÇAISE
*Liberté Égalité Fraternité*

cnes

# FUTURE MISSIONS
## PROGRAMMATIC APPROACH

- **A committee of scientists** is advising CNES Executive on scientific challenges and lays priorities every 5 years.
- **R&D and technology innovation studies** are carried out with our scientific and industrial partners, to support future missions development and new concepts
- Identify programmatic frameworks and funding to engage projects
- Crucial **preparation** with integrated project team, scientists (joint science Teams) & downstream ecosystems
  e.g. SWOT
- **Build strong partnerships with a collaborative spirit**: additive skills, building trust, valuing diversity, common vision & ambition

RÉPUBLIQUE FRANÇAISE
*Liberté Égalité Fraternité*

cnes

# CNES SCIENTIFIC PROSPECTIVE

EO Committee Executive Summary

## OUR PRIORITY MISSIONS

Very high High
- Cooperations
- Copernicus
- ESA : FutureEO - Nav
- EUMETSAT

**C²OMODO/AOS**
Convection, Aerosols & Climate

**CARIOQA**
Quantum gravimetry

**OG2F**
Tahiti Geodetic Reference Observatory

**STRATO-FLEET**
Balloons & Suborbital

**SMASH**
High-revisit Hydrology

**ECO**

**Wivern**

**GENESIS & Doris-Neo**
Terrestrial reference

**ODYSEA**
Ocean currents & winds

Coupling, interfaces and various scales Interactions

Climate cycles and variability

Interactions between internal deep Earth and external envelopes

**SMOS-HR**
Soil moisture & Salinity

**MAGIC/NGGM**
Gravity field

**Cryorad**

**S3-NG-TOPO**
Swath Altimetry for oceanography & hydrology

**4D-Earth**

**Cfosat-NG**

**GEO Color**

**C-MIM**
Constellation of Infrared atmospheric sounders

Prediction, Digital Twins and hazards

Land-Sea Continuum

Socio-ecosystems et biodiversity

**Swot-Loac**

**BIODIVERSITY**

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cnes

# USE OF LIDAR FOR OCEAN COLOUR STUDIES

- Development of collaborations with China, the United States, Italy, and Poland
- International team at the International Space Science Institute (2022-2024)
- Training on marine lidar during the Ocean Optics 2024 conference
- New working group at the International Ocean Color Coordinating Group (2025-)
- CNRS-China project with the State Key Laboratory of Satellite Ocean Environment Dynamics (2025-2026)
- FORUM workshop at ISSI on the development of a network of automatic measurements using ground-based lidar (May 2025)
- ESA project for an ocean profiling lidar space mission (2025-2027)

**Marine Lidar : CNES SPS 2024 Substantial Priority**

# USE OF LIDAR FOR OCEAN COLOUR STUDIES

SCIENCE ADVANCES | RESEARCH ARTICLE

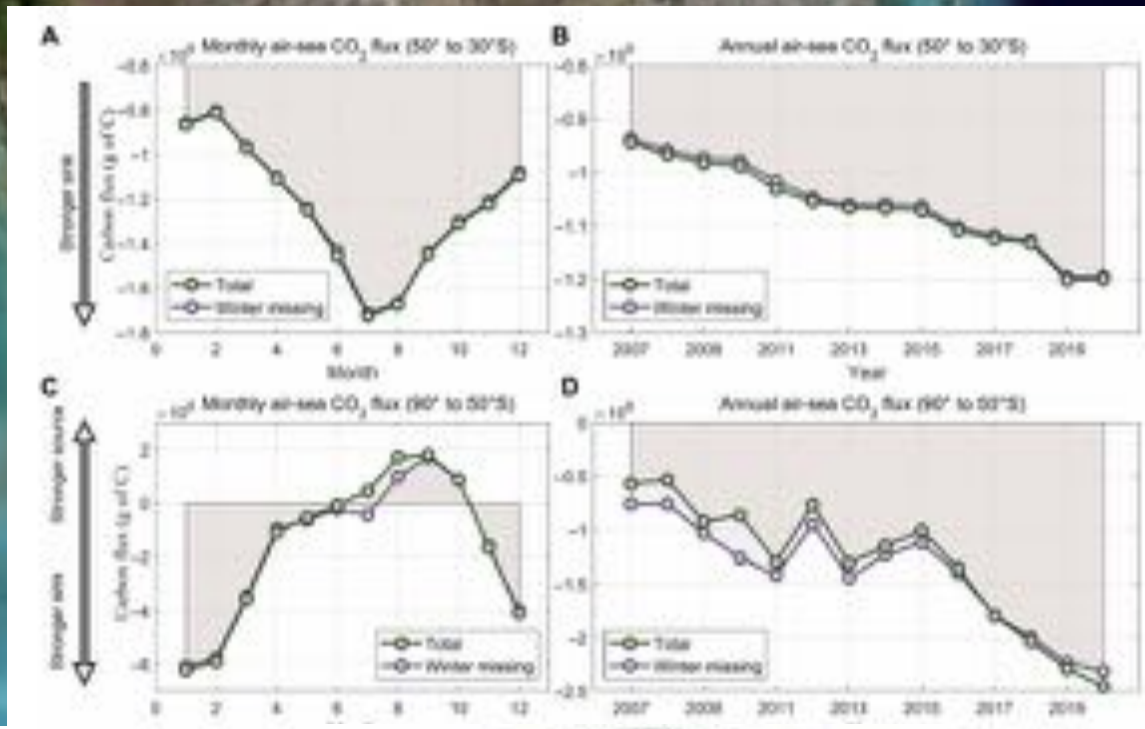
Laboratoire d'Océanologie et de Géosciences

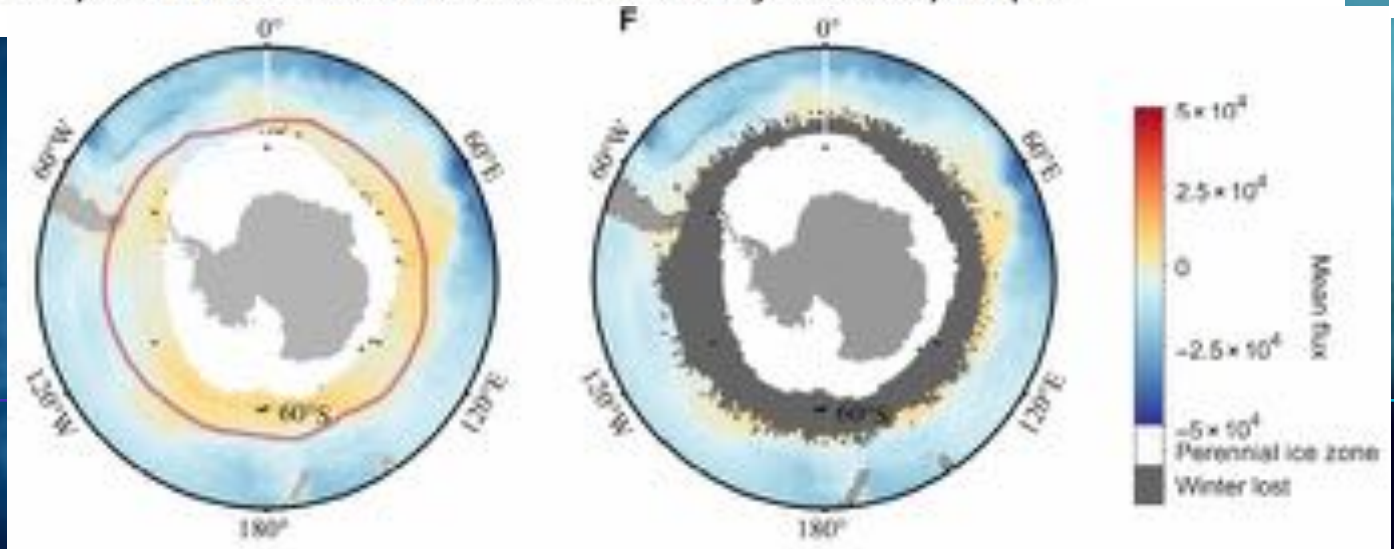
OCEANOGRAPHY

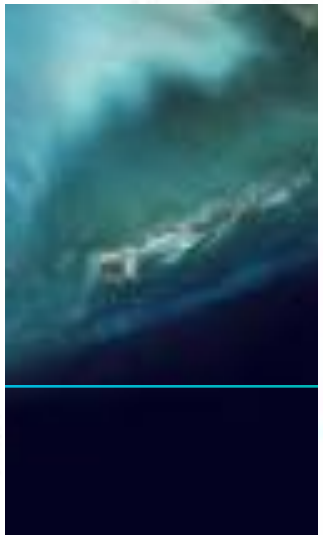
## Substantially underestimated winter $CO_2$ sources of the Southern Ocean

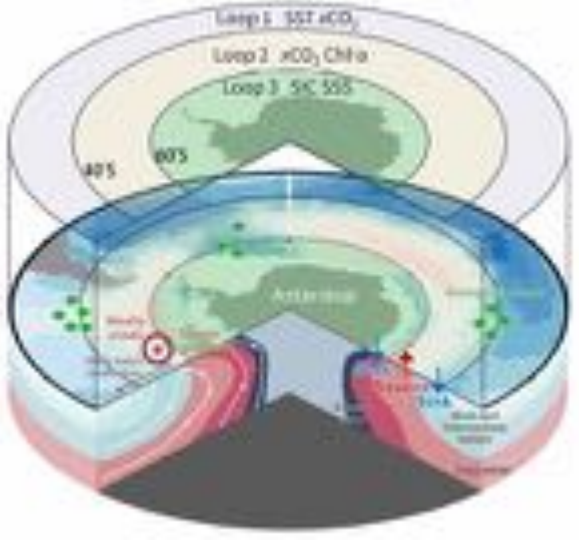
Siqi Zhang[1,2]†, Peng Chen[1,2]*†, Kelsey Bisson[3], Cédric Jamet[4], Paolo Di Girolamo[5], Davide Dionisi[6], Yongxiang Hu[7], Zhenhua Zhang[1,2]*, Kun Shi[8]*, Delu Pan[1,2]

The size and control mechanism of the Southern Ocean's carbon fluxes remain highly uncertain due to sparse winter observations. Here, we integrate satellite light detection and ranging (LIDAR) measurements with machine learning to assess the Southern Ocean air-sea $CO_2$ fluxes between 2007 and 2020. We reveal that $CO_2$ outgassing south of 50°S was underestimated by up to 40% in previous studies. While the midlatitude Southern Ocean (30° to 50°S) strengthens as a carbon sink, the high-latitude region (50° to 90°S) shows Southern Annular Mode (SAM)–modulated alternation between uptake and outgassing. The air-sea $CO_2$ partial pressure difference ($\Delta pCO_2$) increasingly dominates flux variability over wind-driven transfer velocity. We propose a framework involving three latitudinal loops with differing $pCO_2$ controls: (i) Antarctic (salinity/sea ice), (ii) polar front (atmospheric $CO_2$/chlorophyll), and (iii) subpolar (sea surface temperature/$CO_2$). The findings underscore the winter processes' critical role and necessitate year-round observations to understand Southern Ocean's global carbon cycle impact.



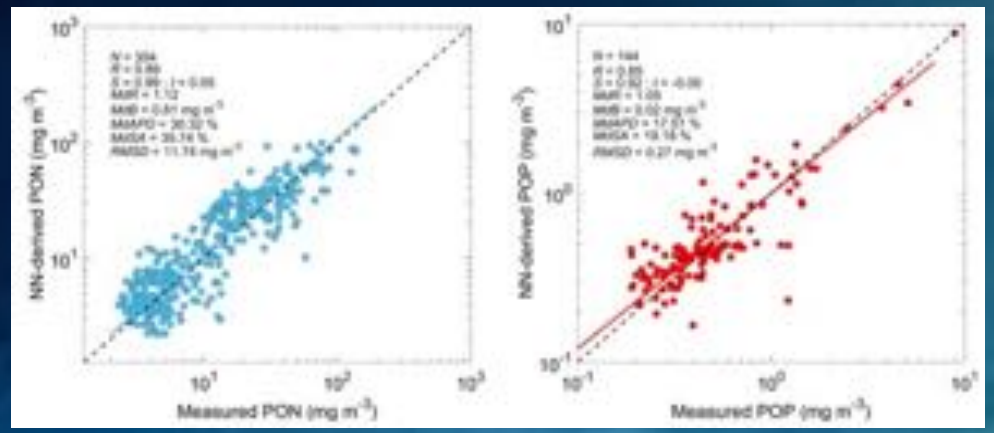



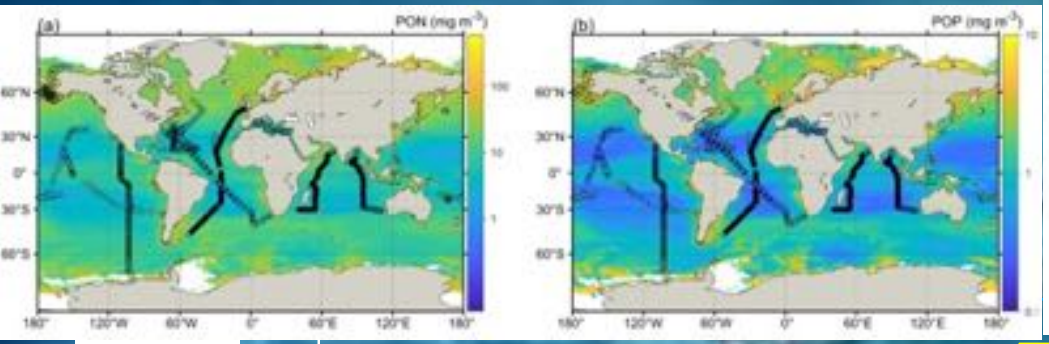





# PROJECT COUL-PNP (PI. H. LOISEL)

Goal: To estimate the particulate organic nitrogen and phosphorus in the ocean (and the C/N/P ratio constraining global biogeochemical cycles) and their spatio-temporal variabilities

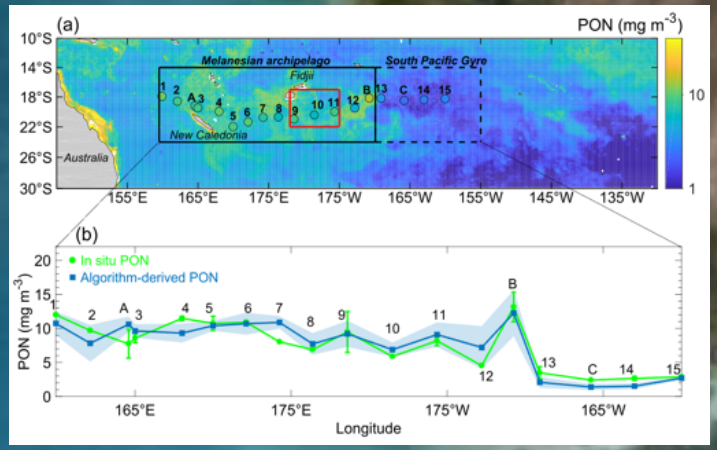


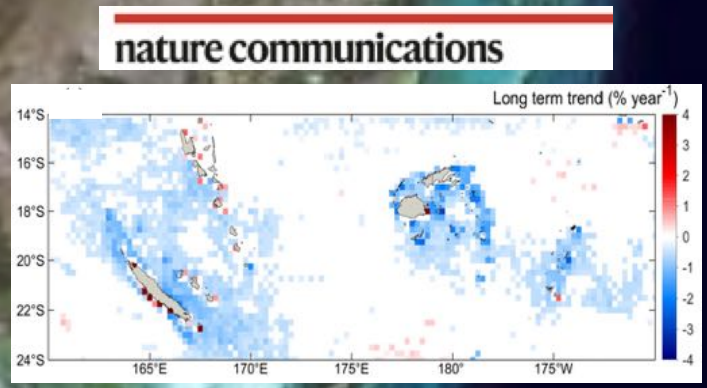




## Regional Application

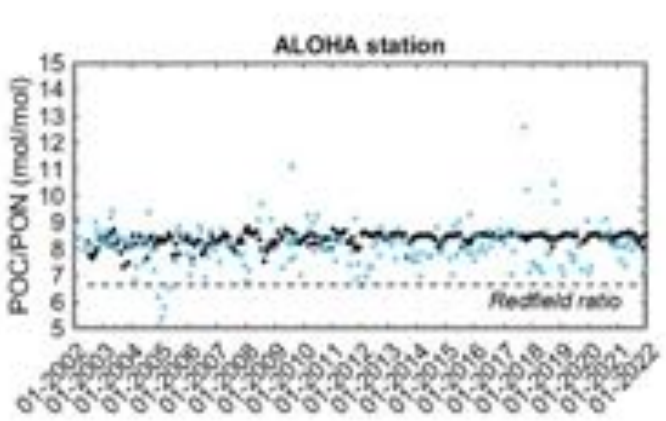
**Long term decline of the planktonic biomass in a hotspot of nitrogen fixation**

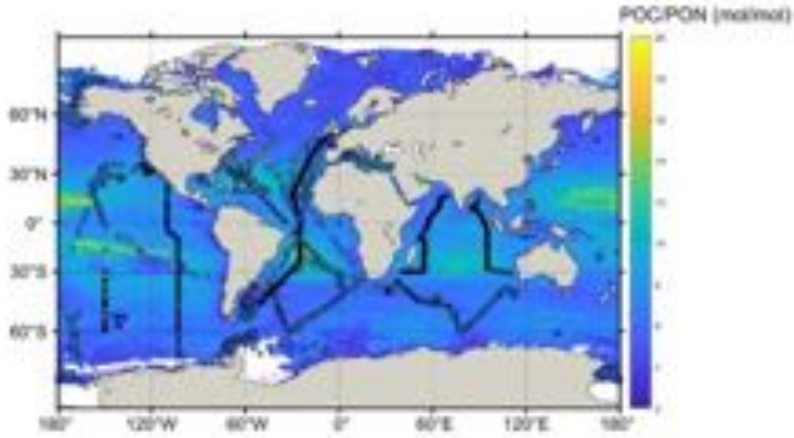
Alain Fumenia, Hubert Loisel, David M. Karl, Vincent Vantrepotte, Anne Petrenko, Sophie Bonnet, Manh Tran-Duy, Marine Bretagnon, Antoine Mangin and Thierry Moutin




## Towards the Redfield ratio




RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cnes

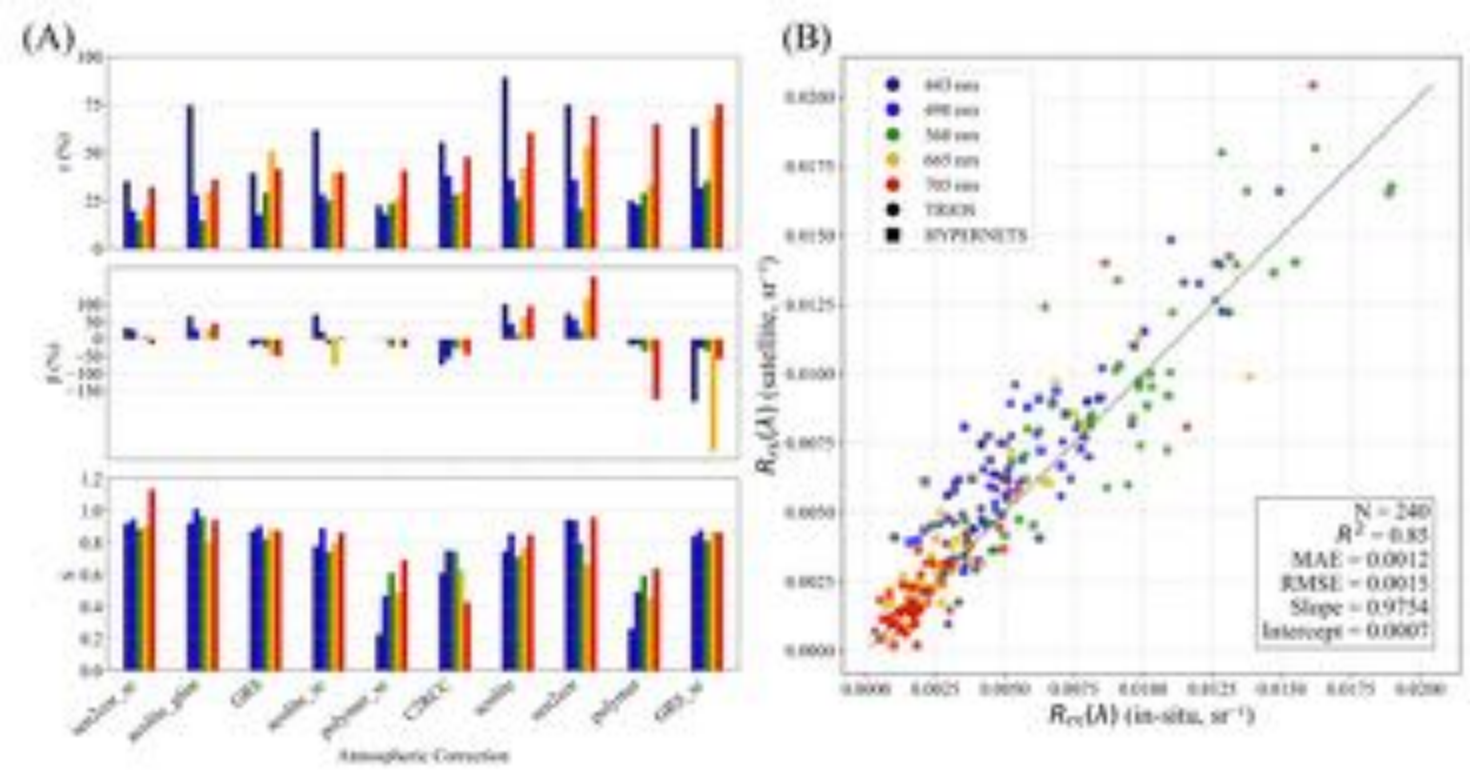
**Link with Geo Colour CNES SPS 2024 Substantial Priority**

# PROJECT HYPERVAL

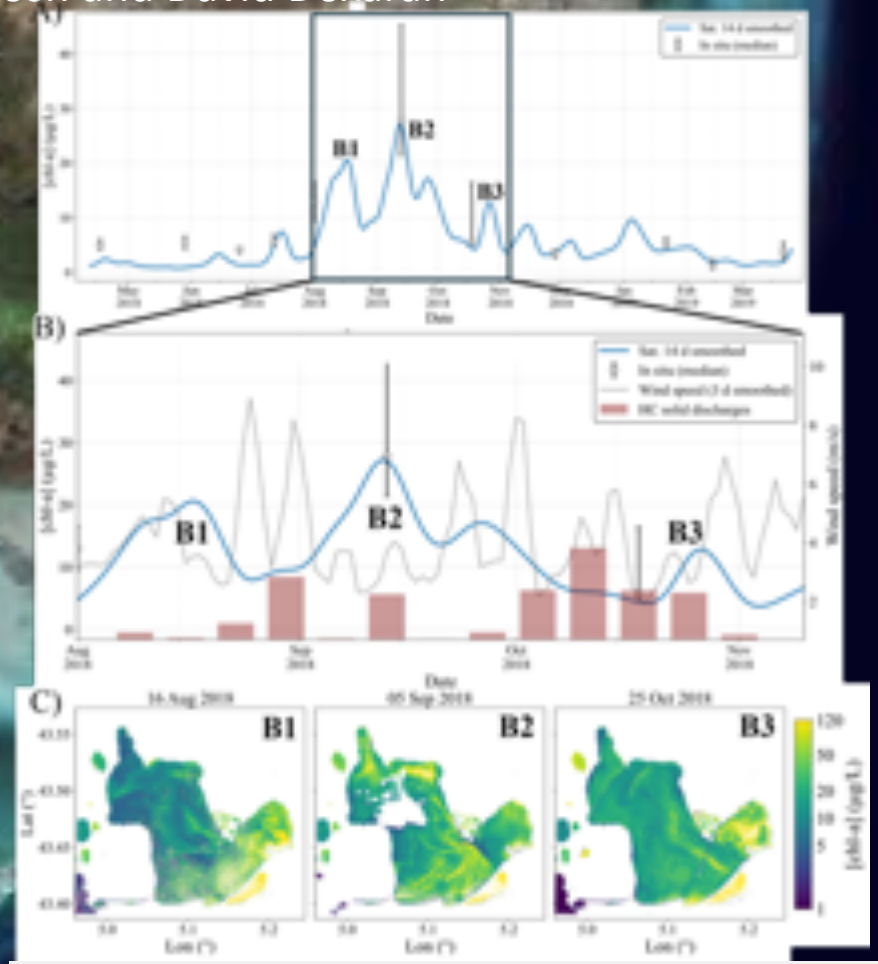
**Towards Reliable High-Resolution Satellite Products for the Monitoring of Chlorophyll-a and Suspended Particulate Matter in Optically Shallow Coastal Lagoons (2025)**

by Samuel Martin, Philippe Bryère, Pierre Gernez, Pannimpullath Remanan Renosh and David Doxaran

Remote Sens. 2025, 17(20), 3430; https://doi.org/10.3390/rs17203430




Intercomparison of atmospheric correction algorithms for retrieving the multispectral reflectance of water in the Berre and Thau lagoons, based on matchups between S2-MSI products and autonomous in situ measurements (HYPERNETS).



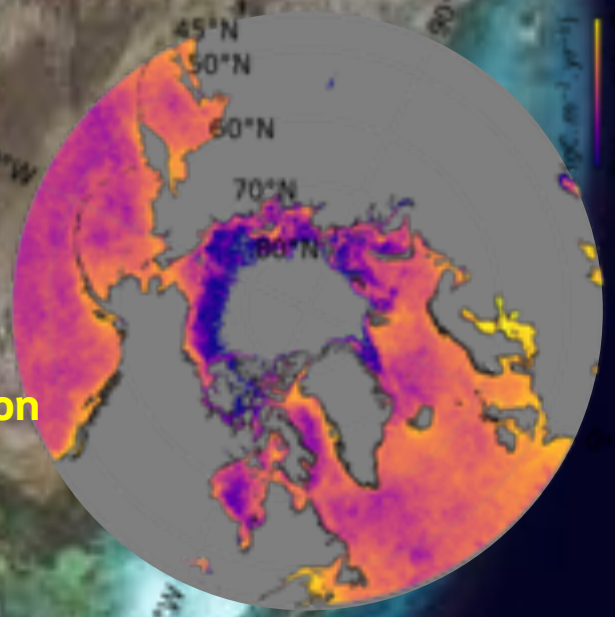

Application: mapping (S2-MSI) and temporal monitoring of sen Chla concentrations in the Étang de Berre during the 2018 ecological crisis.

# PROJECT ALG-O-NORD (ARDYNA, BABIN, NIETO, LI)

**Main objective:** **Improve estimates and trends of Arctic primary production (PP), from local to pan-Arctic scales.**

## Key Steps

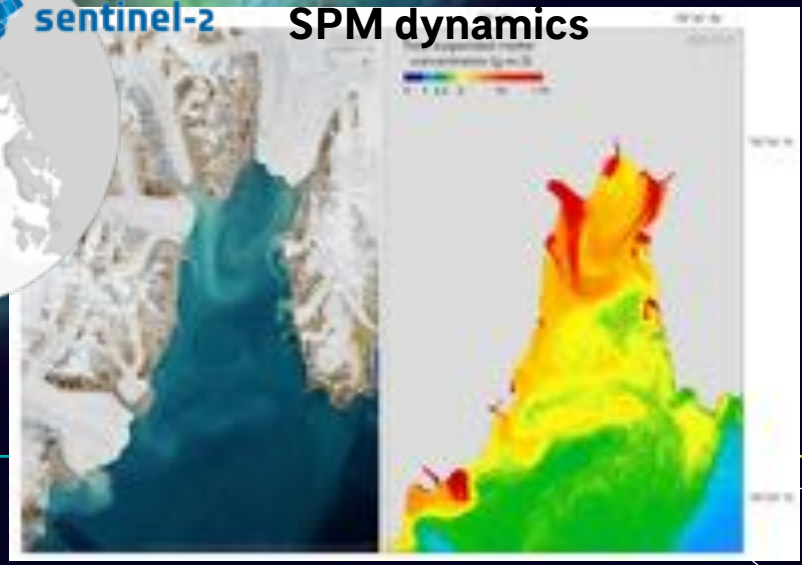
- Validate and develop Arctic-adapted algorithms using unique High Arctic bio-optical datasets
- Better constrain CDOM, SPM, and chlorophyll-a dynamics
- Derive new PP trends in coastal/fjord systems and across the pan-Arctic region




Annual primary production
Takuvik-UQAR model

sentinel-2

SPM dynamics



TAKUVIK cnrs UNIVERSITÉ LAVAL SORBONNE UNIVERSITÉ

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cnes

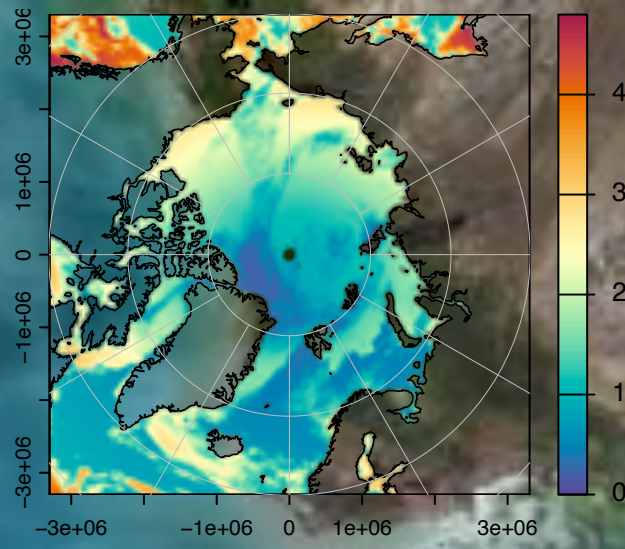
# PROJECT UNDER ICE PAR (BABIN, ARDYNA, LI, NIETO)

**Main Objective: Estimate under ice radiation using state-of-the-art models and parameterizations.**

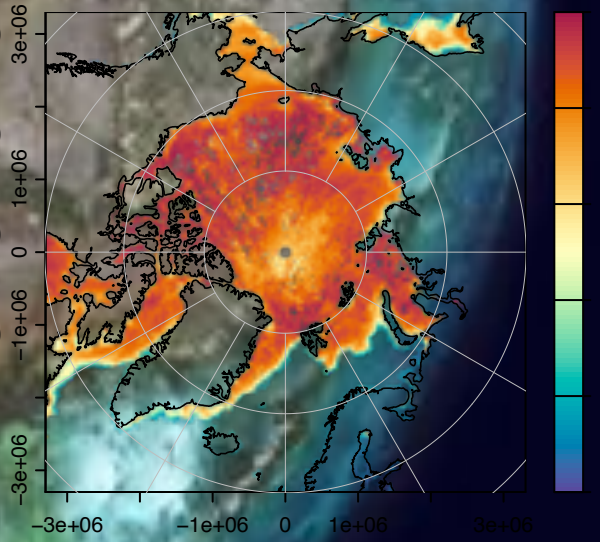
## Key Steps

- Estimate above-surface PAR: quantify the radiation reached at the ice surface
- Estimate PAR albedo: remove the portion reflected back into the atmosphere
- Estimate PAR attenuation within the ice cover: subtract the portion absorbed by the ice

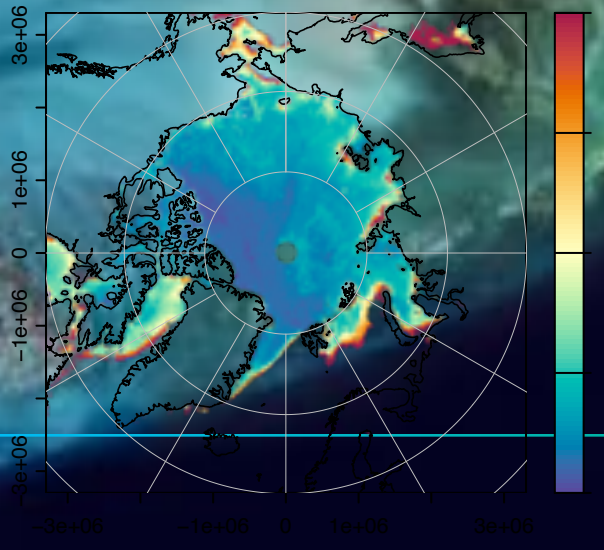
HEIMDALL-modeled above-surface PAR



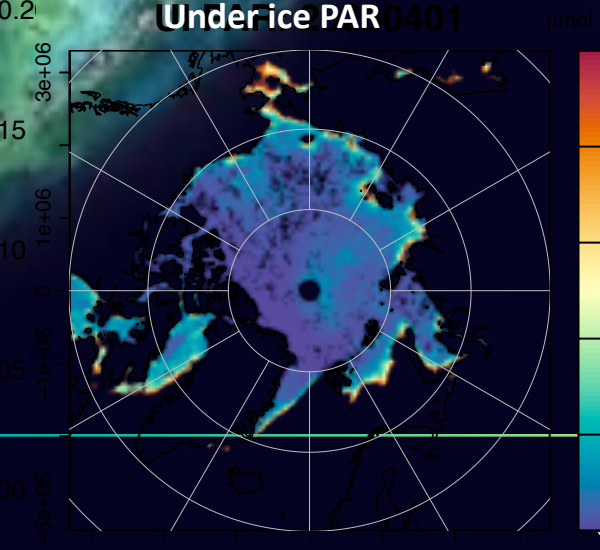

MODIS PAR albedo




PAR attenuation in ice (CryoSat/SMOS)




Under ice PAR




TAKUVIK cnrs UNIVERSITÉ LAVAL SORBONNE UNIVERSITÉ

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

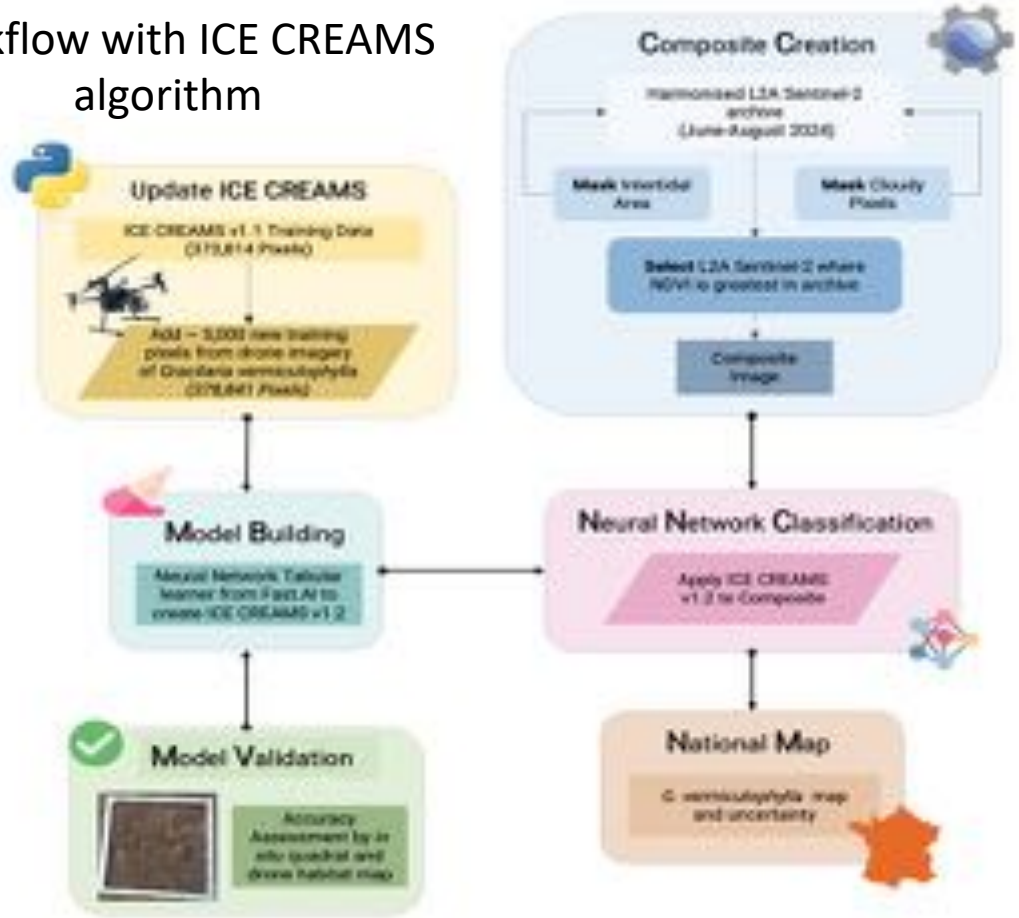
cnes

# PROJECT INVASEA
# REMOTE SENSING OF INVASIVE MACROALGAE IN COASTAL AREAS (BARILLÉ, GERNEZ)

Nantes Université

Mapping the Distribution of an Intertidal Invasive Red Macroalgae at a National Scale Using Satellite Remote Sensing

Workflow with ICE CREAMS algorithm




RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cnes

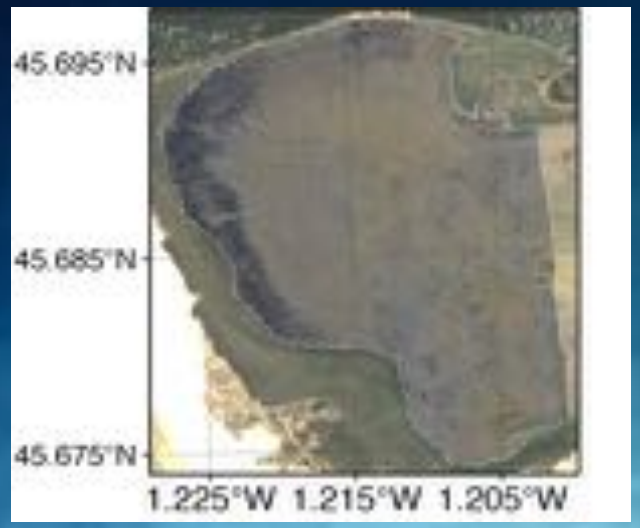
# PROJECT INVASEA
# REMOTE SENSING OF INVASIVE MACROALGAE IN COASTAL (BARILLÉ, GERNEZ)

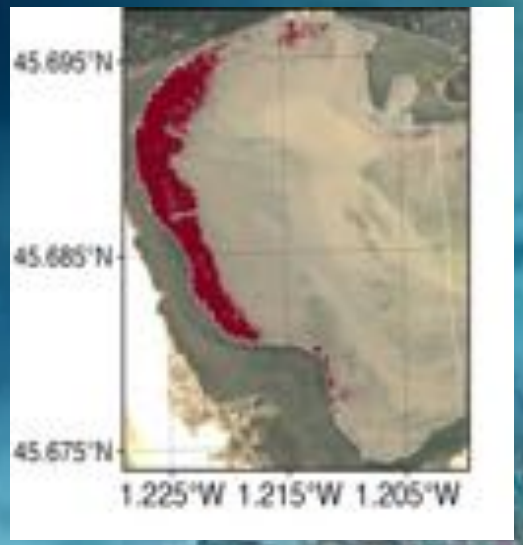
Google Earth Engine

Nantes Université

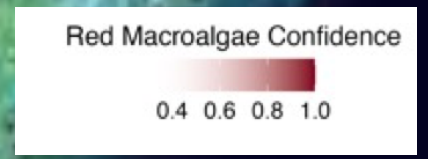
## ICE CREAMS ALGORITHM

Intertidal Classification of Europe: categorising Reflectance of Emerged Areas of Marine vegetation with Sentinel-2.








Spatial distribution of *Gracilaria vermiculophylla* in Bonne Anse

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

cnes


Thank you for your attention