

# Emerging Applications and Science from ESA

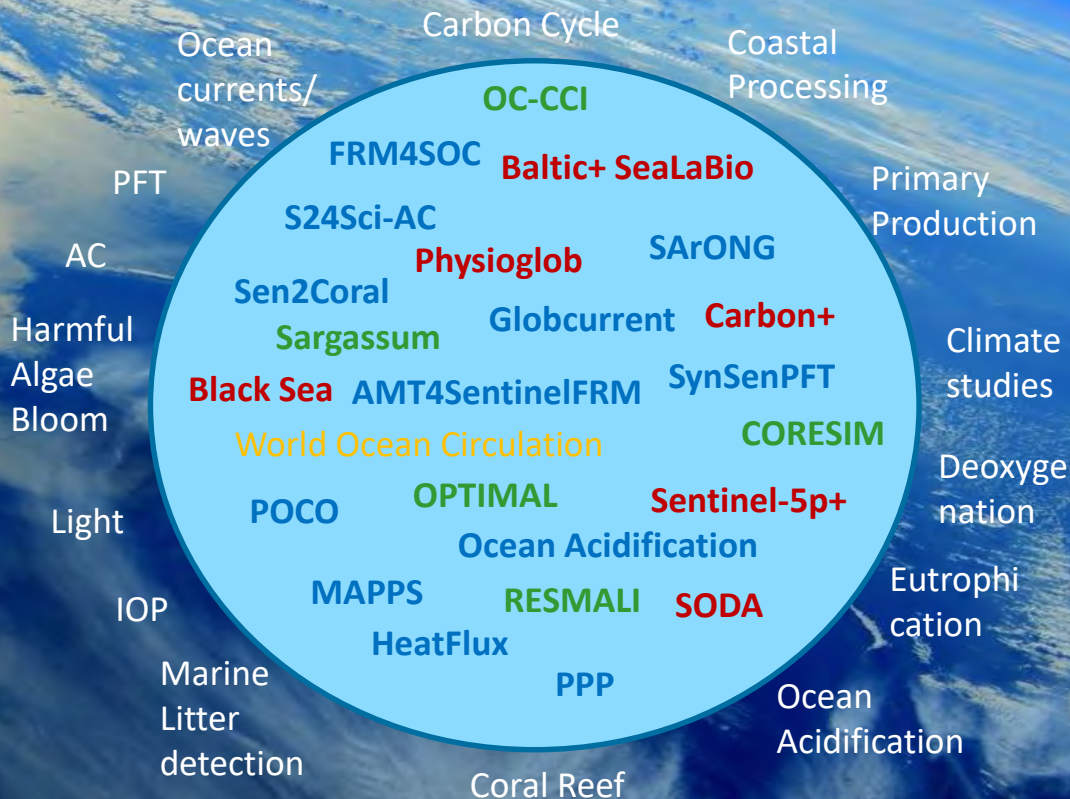
IOCS 9-12 April 2019  
Busan, South Korea

**Marie-Helene RIO,**  
**Ocean Applications Scientist**  
**ESRIN-ESA**



# Emerging Applications and Science from esa

Past Projects Running Projects Just started Projects In preparation Topic

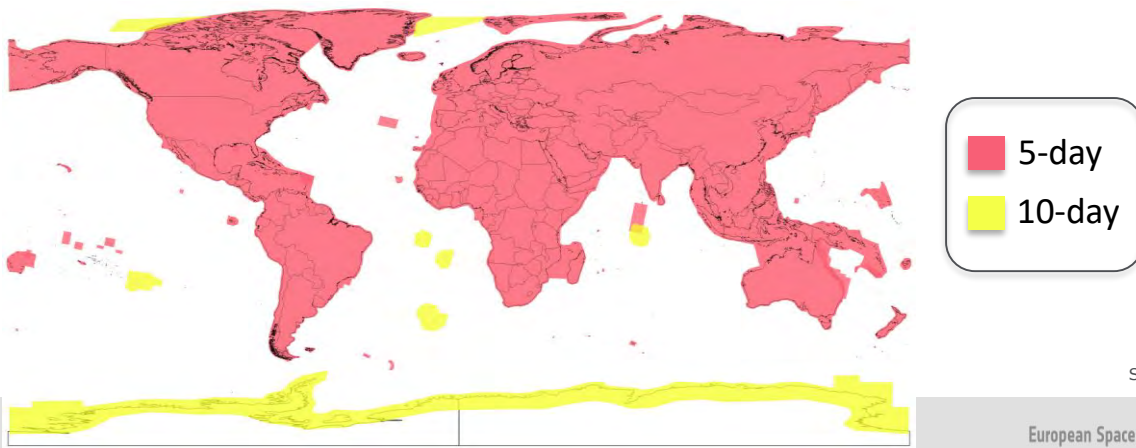




# Sentinel-2 mission Status

- Sentinel-2A and Sentinel-2B mission operations → **nominal**
- Monitoring of inland coastal waters and all coastal waters up to 20 km from the shore, all islands greater than 100km<sup>2</sup>, all EU islands, the entire Mediterranean Sea, all closed seas
- **Data acquisitions with 5-day revisit** since February 2018
- **Level-2A (surface reflectance)** products generated and distributed with **global coverage** since 13 December 2018 (European acquisitions since March 2018)

## Sentinel-2 Observation Scenario with Revisit Time





# Sentinel-2 mission Status



## S2-Related Ressources

- **Sentinel-2 Mission Status Reports** available at:

<https://sentinel.esa.int/web/sentinel/missions/sentinel-2/mission-status>

- **Data Quality Reports** available at:

[https://sentinels.copernicus.eu/documents/247904/685211/Sentinel-2\\_L1C\\_Data\\_Quality\\_Report](https://sentinels.copernicus.eu/documents/247904/685211/Sentinel-2_L1C_Data_Quality_Report)

<https://sentinels.copernicus.eu/documents/247904/685211/Sentinel-2-L2A-Data-Quality-Report>

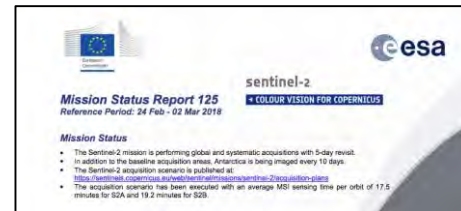
- **SNAP**: Visualisation & processing of Sentinel-2 MSI data and other optical data: <http://step.esa.int/>

- **sen2cor**: Level-2A processor:

<http://step.esa.int/main/third-party-plugins-2/sen2cor/>

- **EO-BROWSER**: Visualisation of Sentinel-2, Sentinel-3, Landsat, Proba-V data:

<http://apps.sentinel-hub.com/eo-browser/>

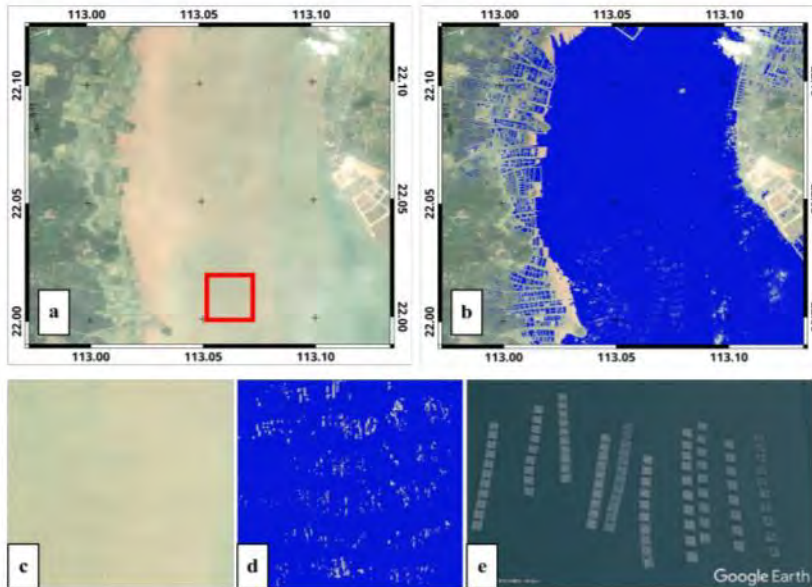




## Sentinel-2 Atmospheric Correction

2016-2018 Consortium: ACRI (FR), INFORMUS GMBH (DE), ULCO (FR)

**Objective:** develop and validate an atmospheric corrections scheme to produce high quality surface reflectance from Sentinel-2 data for coastal waters.



- (a) RGB S-2 image over the Huangmao river estuary in China.
- (b) Results of the water pixel extraction by WiPE.
- (c) Zoom of the area framed in (a) showing the fish cages which are also identified with WiPE in (b) and zoomed in (d).
- (e) Fishes cages showed from Google Earth image

*Ngoc et al, 2019, RSE*

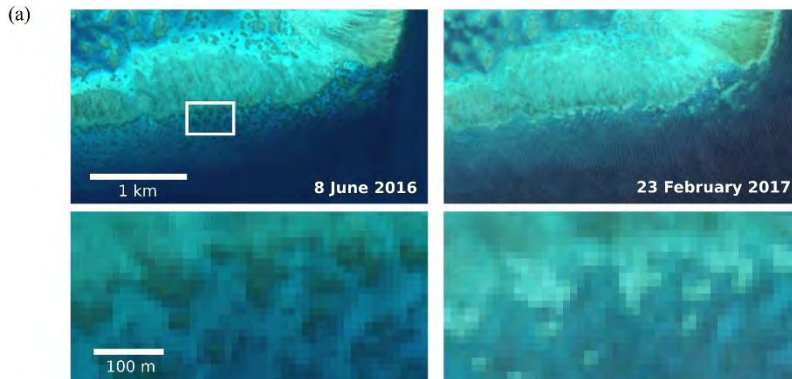
Slide 5



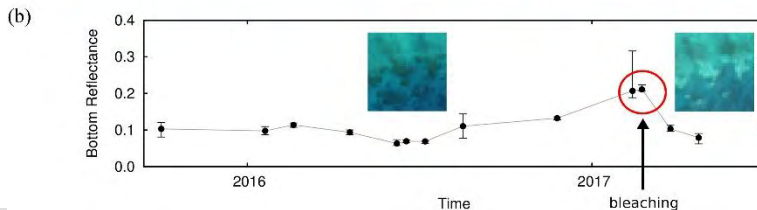
## Sen2Coral

2016-2018: Argans Limited (GB), CNR (IT), CS (FR)

**Objective:** develop and validate new algorithms relevant for coral reef monitoring based on Sentinel-2 observations, including benthic mapping, coral reef health and mortality as well as bathymetry.



Bleaching as visible in Sentinel-2A imagery at Adelaide reef in February 2017, in comparison to June 2016.



*Hedley et al, 2018, RSE*

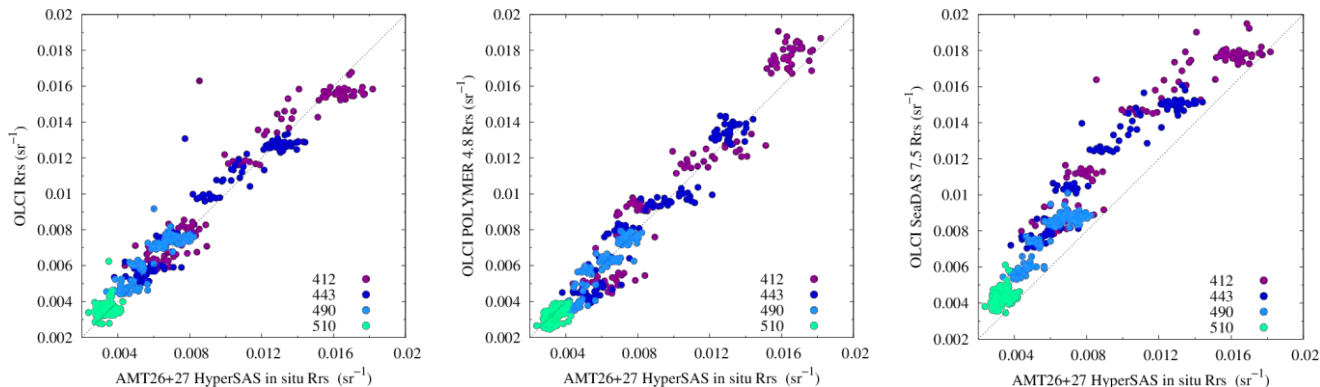


## AMT4SentinelFRM

PI: Gavin Tilstone PML (UK), Partners: University of Southampton (UK) , IFREMER (FR)

**Objective:** providing high quality Fiducial Reference Measurements (FRM) to validate satellite data during the Atlantic Meridional Transect (AMT) annual research voyage between the UK and destinations in the South Atlantic.

## Evaluating Sentinel-3 OLCI



*Courtesy Silvia Pardo*

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# Ocean Colour Climate Change Initiative



ESA CCI: R&D Programme (2010-2024) to exploit the full potential of Earth Observation in support of Climate Research and Assessment. **Objective:** Produces long time-series of Essential Climate Variables (ECV)

**OC-CCI Consortium:** PML, Telespazio Vega, Brockmann Consult, HZG, Nersc, JRC, Hygeos, FCUL, CNR

## OC-CCI V4 is Ready for Release:

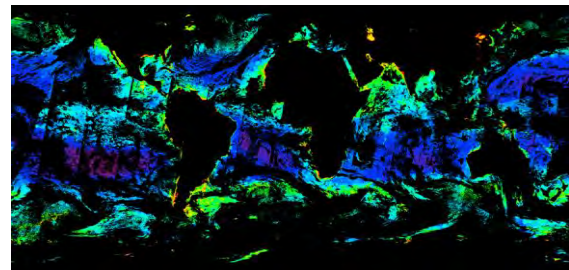
Daily, 4km maps of

**OC:** Chl-a, Rrs, Kd490, **IOP:**  $\alpha_{\text{tot}}$ ,  $\alpha_{\text{dg}}$ ,  $\alpha_{\text{ph}}$ ,  $b_{\text{bp}}$

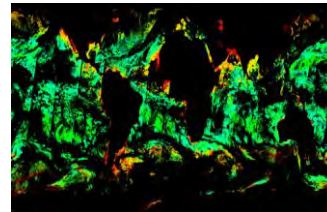
## Main improvements compared to V3:

- Reprocessing updated following NASA R2018
- Uncertainty estimation
- Updated in situ database for validation

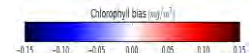
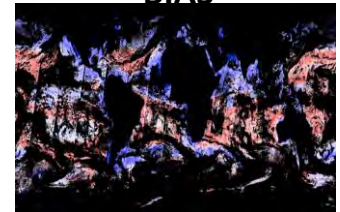
### Chl-a - 1 Jan 2003



### RMSD



### BIAS



Courtesy: Shubha Sathyendranath

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ESA's R&D Programme (2010-2024) to exploit the full potential of Earth Observation in support of Climate Research and Assessment

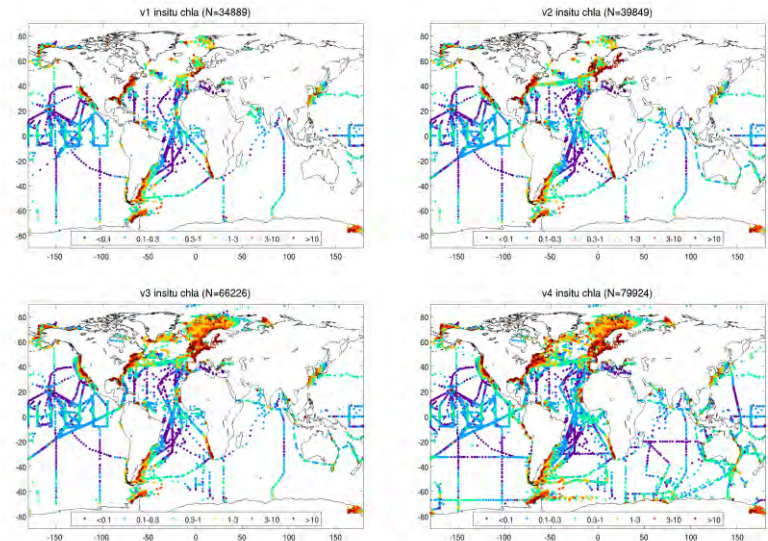
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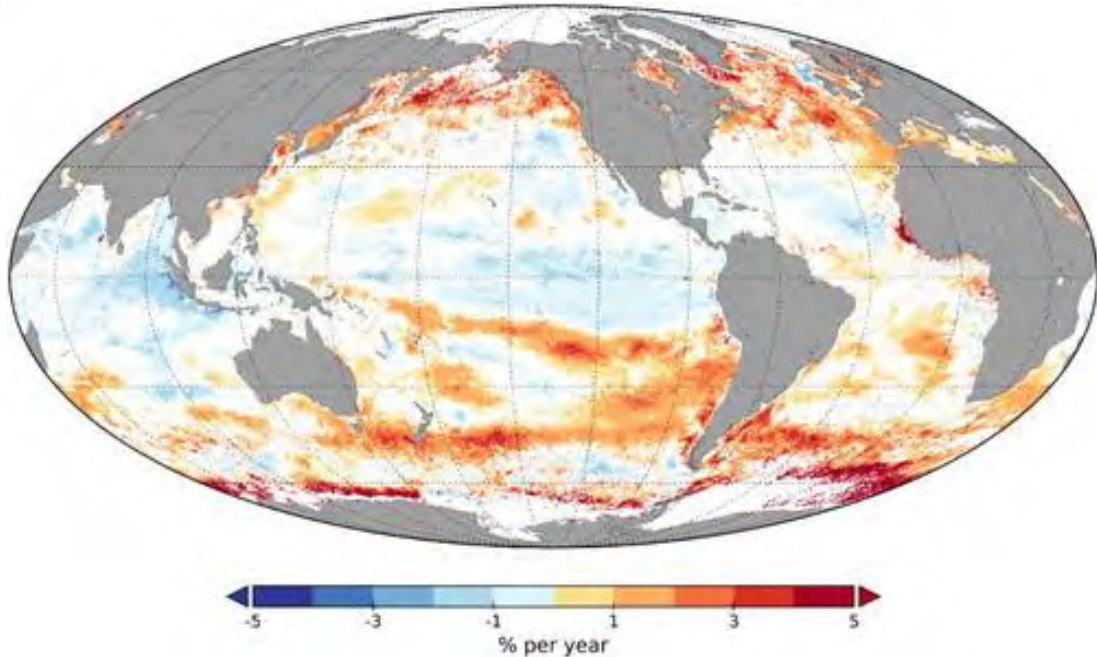


*Valente et al. 2019: A compilation of global bio-optical in-situ data for ocean colour satellite applications, PANGAEA*





## OC-CCI Chlorophyll Trends (Sep 1997 – Dec 2016)

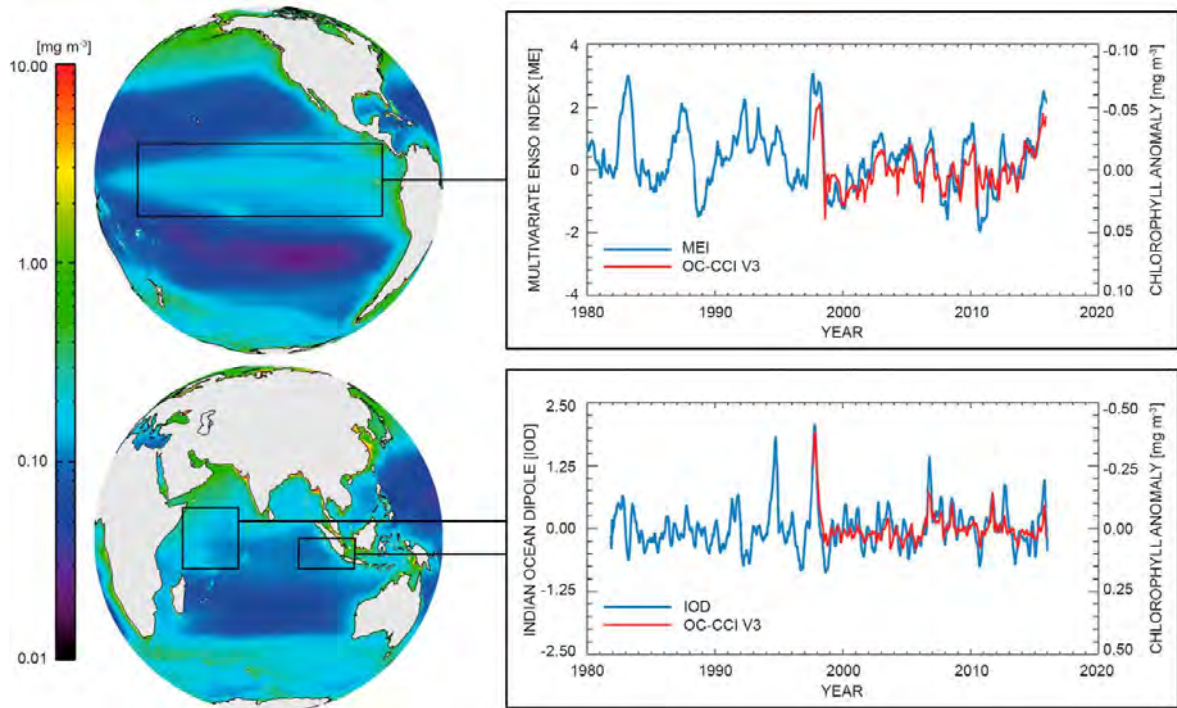


CMEMS Ocean State Report (2018)





## OC-CCI Chlorophyll Variability



CMEMS Ocean State Report (2016)



# PhysioGlob project – Living Planet Fellowship

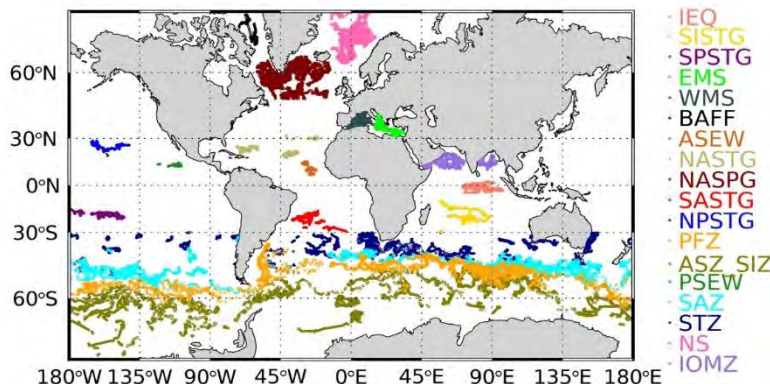


December 2018-December 2020

Dr. Marco Bellacicco (ENEA, IT)

**Objective:** study the inter-annual physiological response of phytoplankton to the global warming using long-term satellite observations (*i.e.* entire ESA OC-CCI time-series) through the well known chlorophyll-*a* to carbon ratio ( $\text{Chl:C}_{\text{phyto}}$ ) index

BGC-Argo dataset on a global ocean scale.  
Colors correspond to specific bioregion



- 1) Use a large in-situ dataset field of remote-sensing reflectance ( $R_{rs}$ ) and inherent optical properties (IOP) to update the Quasi Analytical Algorithm (QAA) presently used in the ESA OC-CCI to better estimate particle backscattering ( $bbp$ ,  $\lambda$ );
- 2) To develop a new phytoplankton carbon biomass ( $C_{\text{phyto}}$ ) satellite product based on the updated version of QAA;
- 3) To extract and study trend and oscillations of the physiological signal ( $\text{Chl:C}_{\text{phyto}}$  ratio) and its relationship with sea surface temperature on a global ocean scale.

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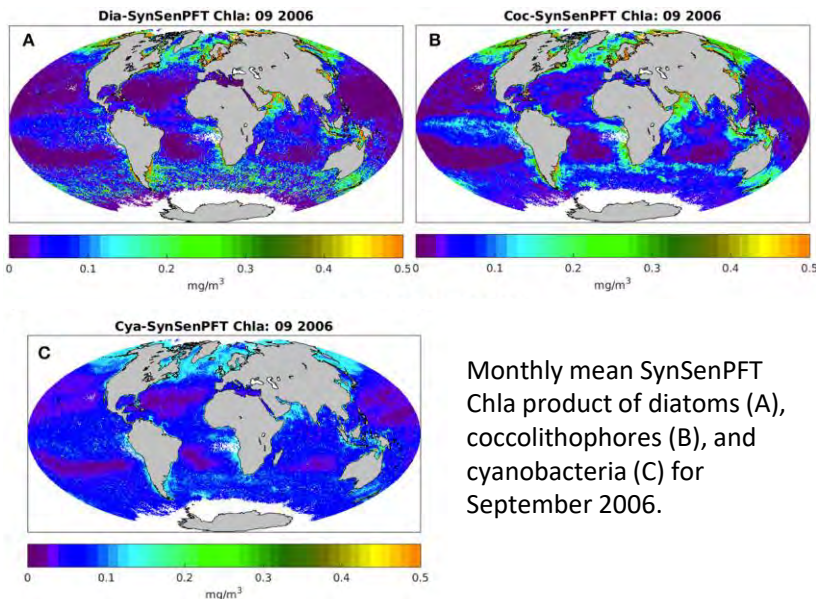


## SynSenPFT Project 2014-2016

Consortium: AWI (DE), IUP-UB (DE), LOV/UPMC (FR), PML(UK)

Synergistic Exploitation of Hyper-and Multispectral Sentinel-Measurements to Determine Phytoplankton Functional Types (PFT)

Objective: developing a synergistic product which contains the Chl-a (biomass) of several PFT by using complementary information from multi- and hyper-spectral satellite ocean colour data (SCIAMACHY). This algorithm can be later applied to produce a synergistic PFT product from TROPOMI (on Sentinel-5-Precursor, Sentinel-4, Sentinel-5) and OLCI (on Sentinel-3).



Monthly mean SynSenPFT Chla product of diatoms (A), coccolithophores (B), and cyanobacteria (C) for September 2006.

*Losa et al, 2017, Frontiers in Marine Science*



## Sentinel-5p+ project (to be kicked-off in May)



Capitalizing on the SynSenPFT project, a new project is being kicked off to exploit the very high spectral resolution of the TROPOMI sensor on Sentinel-5p to observe Phytoplankton Functional Types (PFTs), chlorophyll a (Chla) fluorescence and light penetration depth.



### Objectives of the project:

- Develop ocean colour (OC) products (e.g. Chlorophyll, PAR, SIF) for Sentinel-5p;
- Explore the potential of the UV range of Sentinel-5p for ocean biology.
- Assess the synergies with other satellite sensors, in particular explore the synergistic use of Sentinel-5p and Sentinel-3;
- Validate with established reference in-situ datasets and perform intercomparison to other satellite measurements (e.g. MODIS, OLCI);
- Assess existing algorithm which have been used for ocean colour product retrievals from e.g. SCIAMACHY and GOME-2.



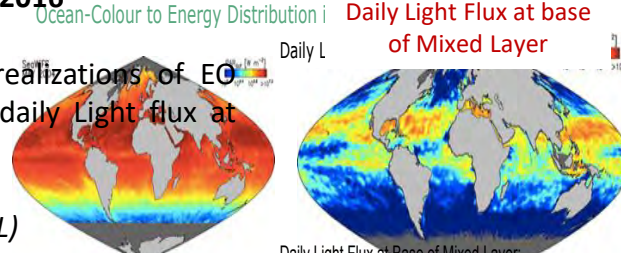
# Toward the better characterization of the marine carbon cycle from space?



## Ocean HEATFLUX Project 2014-2016

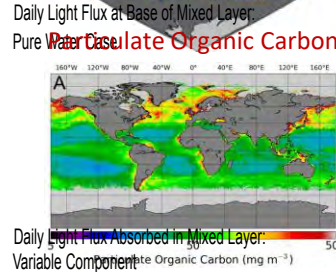
Ifremer, Nersc, PML, MIO, DWD

**Objective:** generate multiple realizations of EO based flux products including daily Light flux at the base of the Mixed Layer

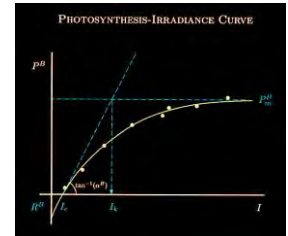


## MAPPS Project 2014-2016 (PML)

**Objective:** to assemble a global database of photosynthesis– irradiance (P-E) parameters from a range of oceanographic regimes



Photosynthesis– irradiance (P-E) curve

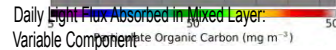


**Bouman et al (2018) ESSD**

## POCO project 2015-2017

PML, HZG, U.Southampton, U.Reading

**Objective:** To explore novel methods to quantify particulate, and dissolved, pools of carbon in the ocean

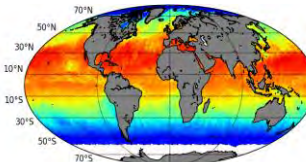


**Hayley Evers-King et al, 2017**

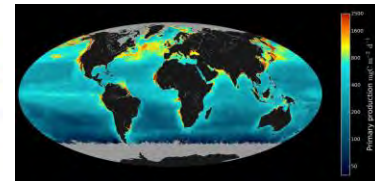
## PPP Project 2015-2017 (HYGEOS, PML)

**Objective:** To develop a daily PAR product from ENVISAT/MERIS and Sentinel 3/OLCI and application of these products to the Primary Production modelling.

ESA PAR product



ESA integrated primary production product





# Toward the better characterization of the marine carbon cycle from space?



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*Ifremer, Nersc, PML, MIO, DWD*

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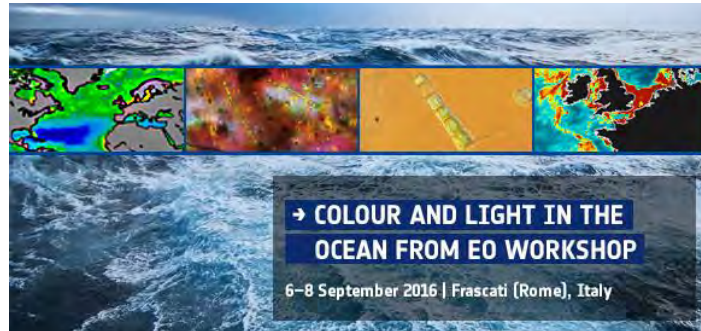
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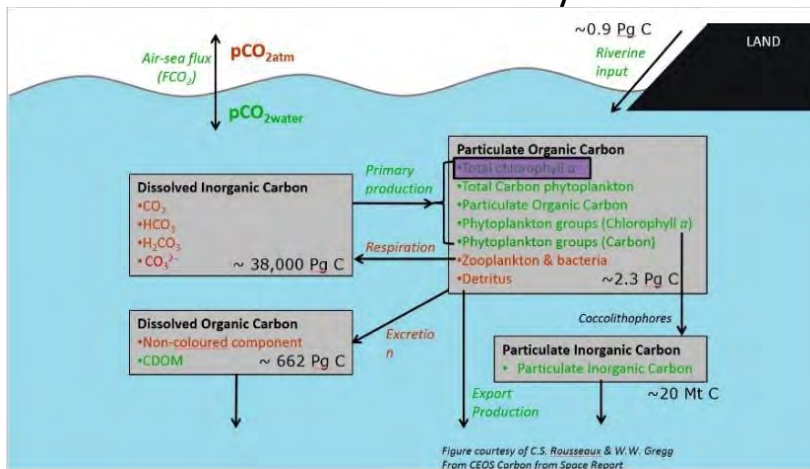


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# Toward the better characterization of the marine carbon cycle from space?

CLEO Final report: “the full quantification of the upper ocean biological carbon pump using remote sensing products **seems no longer out of reach**, and would be essential to better constrain marine ecosystem and climate models “



**Carbon+ 2-year project** Objective: better characterise the different components of the biological carbon pump and compute its budget (carbon pools and fluxes) from space. **to be kicked off very soon**



OA project 2014-2016

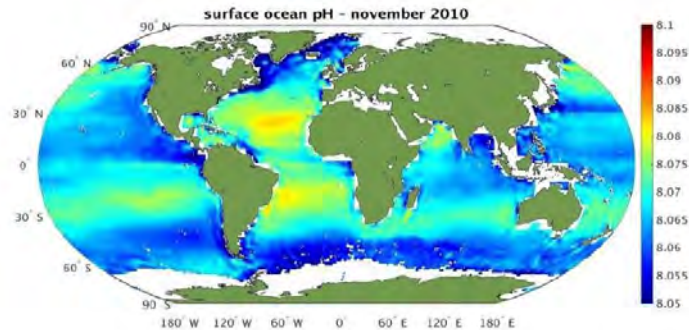


**Objective:** to develop/validate algorithms to retrieve OA parameters from space.

There are four key OA parameters: total alkalinity (TA), dissolved inorganic carbon (DIC), pH, and fugacity of CO<sub>2</sub> (fCO<sub>2</sub>).

All of them are largely driven by **temperature, salinity and biological activity**, allowing **empirical relationships** to be developed using **in situ measurements of OA parameters**.

**New project has just been kicked-off on Ocean Acidity retrieval (OCEAN SODA)**



First-ever estimates of EO-based global surface ocean pH **using SMOS SSS, satellite SST & ocean color**.  
(credits: ESA/R. Sabia)

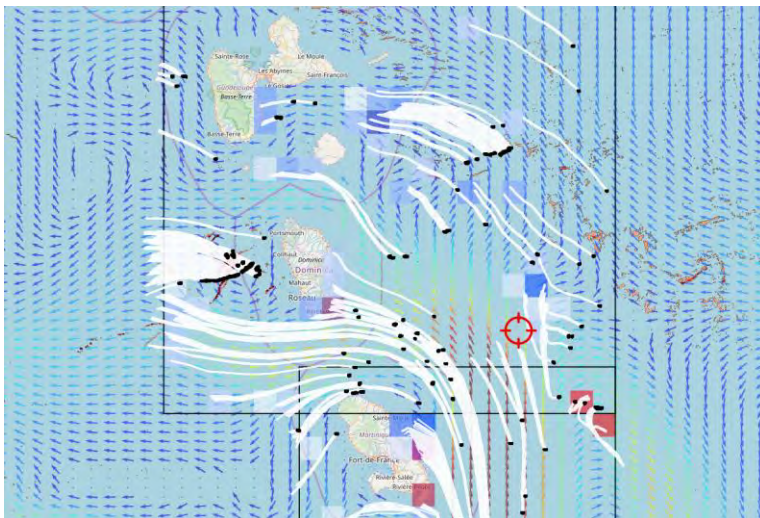


# The Sargassum monitoring service



Open-call project September 2018-September 2019 CLS

**Objective:** develop and implement an **innovative automated service based on Earth Observation (EO) data to monitor floating Sargassum algae** in the Caribbean area, estimate their drift and eventual landings on the coasts, and provide dedicated bulletins to the end-users



Visualisation of results on the web platform

The demonstration phase **has started on April, 1<sup>st</sup>**. More than **50 end-users** will be testing the service during a two-month demonstration phase

<https://datastore.cls.fr/cls-operational-sargassum-monitoring-service-ready-for-end-users/>

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# Regional Initiatives

Baltic  
March 2017, Helsinki

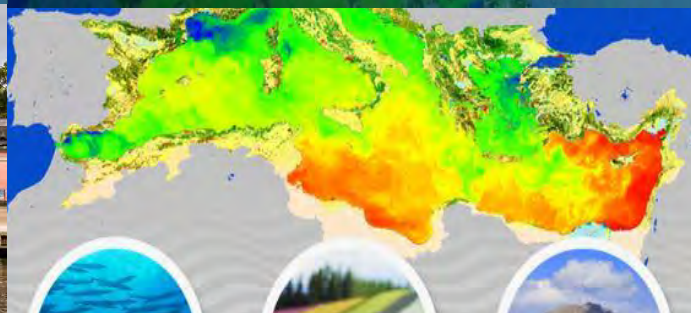


Black Sea/Danube/Balkans  
June 2018, Sofia



med 2018

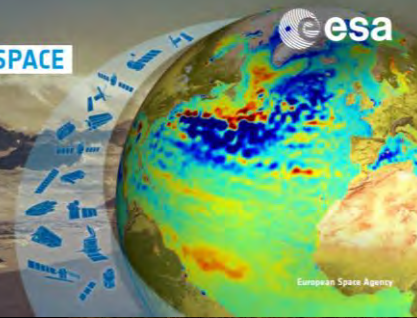
11–13 December 2018 | ESA–ESRIN | Frascati (Rome), Italy



→ ATLANTIC FROM SPACE  
WORKSHOP

23–25 January 2019  
National Oceanography Centre  
Southampton, UK

[www.esa.int](http://www.esa.int)



European Space Agency



Dec 2018 to May 2020

Syke, Brockmann Consult, Brockman Geomatics,  
Solvo, LIOW, Baltic Earth

## Specific Objectives:

- Improved atmospheric correction of Sentinel 2 and Sentinel 3 data
- Successful retrieval of water optical properties and water constituent concentrations in different locations and seasons
- Exploiting synergistic and complementary use of Sentinel 3 and Sentinel 2
- Retrieval of higher level products: eutrophication and sediment transport
- Improve biogeochemical model calibration and validation
- Analysis of results with respect to carbon cycle, eutrophication and water quality



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# Black Sea project



2-year project  
Kick-off in  
May 2019



Ocean color Sentinel 2  
data, Figure from  
Niculescu and Rusu, 2018.

## Specific tasks:

- New, regional algorithm for deriving high quality Chl-a, total Suspended Matter, water turbidity from Sentinel 2 and 3
- Production of gap-free level 4 ocean colour products
- Assimilation of new datasets in an operational CMEMS BS biogeochemical model

## Scientific Study: Deoxygenation

- quantify mesoscale eddies contribution to respiration and ventilation in the open Black Sea
- monitor riverine nutrients and organic matter loads which are important seasonal hypoxia drivers.
- Revise primary production estimate which is directly involved in the deoxygenation budget

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# Marine Litter detection from Space



ESA running activities to investigate the feasibility to detect marine litter in EO optical measurements and provide mission concept and requirements to remotely sense ocean plastics using satellites as platforms.

**OptiMAL (Optical methods for MARine Litter detection)** PML  
**RESMALI** Argans Ltd



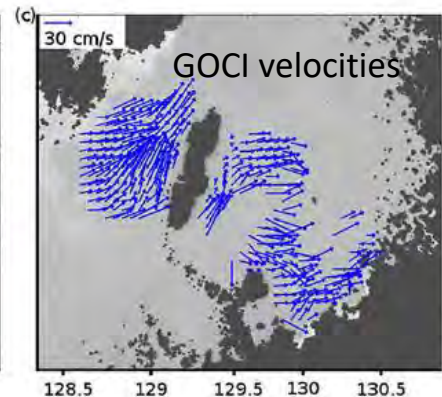
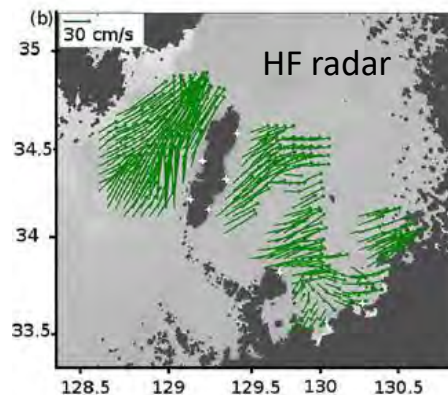
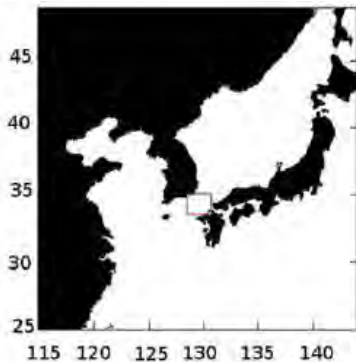
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2014-2019 Consortium: Nersc, Ifremer, CLS, ODL, IsardSat

**Objective:** To advance the quantitative estimation of ocean surface currents from satellite sensor synergy and demonstrate impact in user-led scientific, operational and commercial applications

Application of the **Maximum Cross Correlation (MCC)** on **GOCI (Geostationary Ocean Color Imager)** Ocean Color images in the Tsushima Strait



*Warren et al, 2016, JGR*

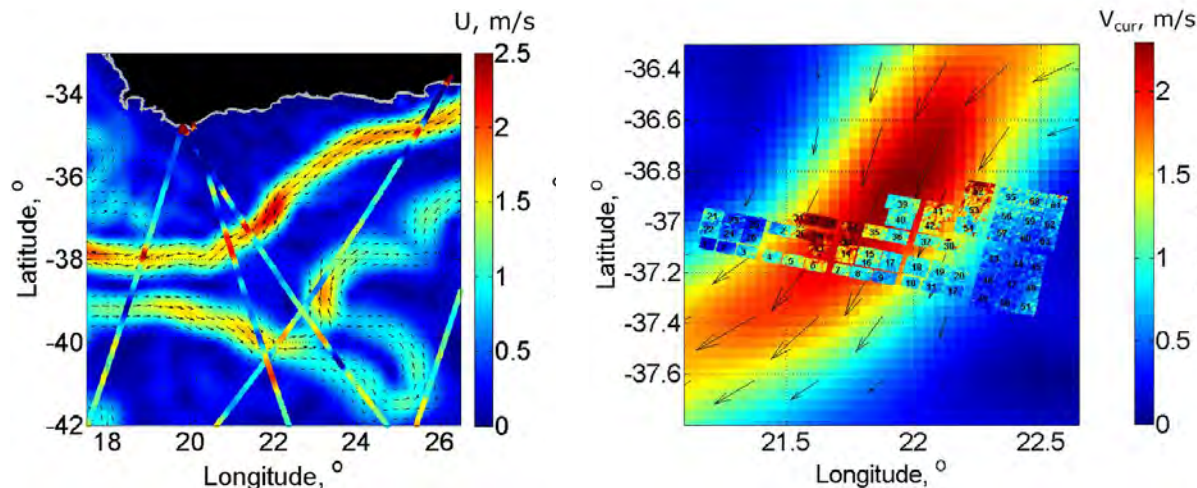


# The SArONG project: Scientific Assessment of Ocean Glitter



2016-2018 Brockmann Consult GMBH, OceanDataLab, Ifremer, University of Exeter

Sentinel-2 MSI measurements provide spectacular and novel quantitative ocean **surface wave directional** measurements in **satellite Sun Glitter Imagery** (SSGI), with high spatial resolution (10m), allowing to advance the understanding and modelling of **ocean wind-wave-current interactions**



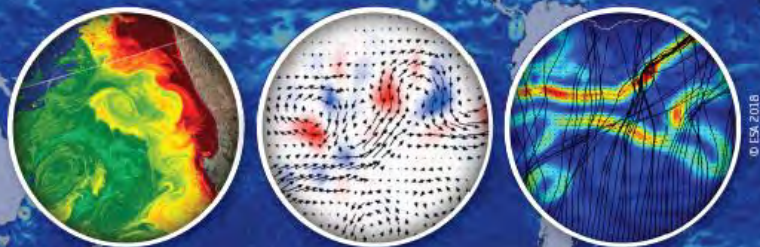
*Kudryavstev et al, 2017, JGR*

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# → WORLD OCEAN CIRCULATION USER CONSULTATION MEETING

21-22 February 2019  
ESA-ESRIN | Frascati (Rome), Italy



© ESA 2018

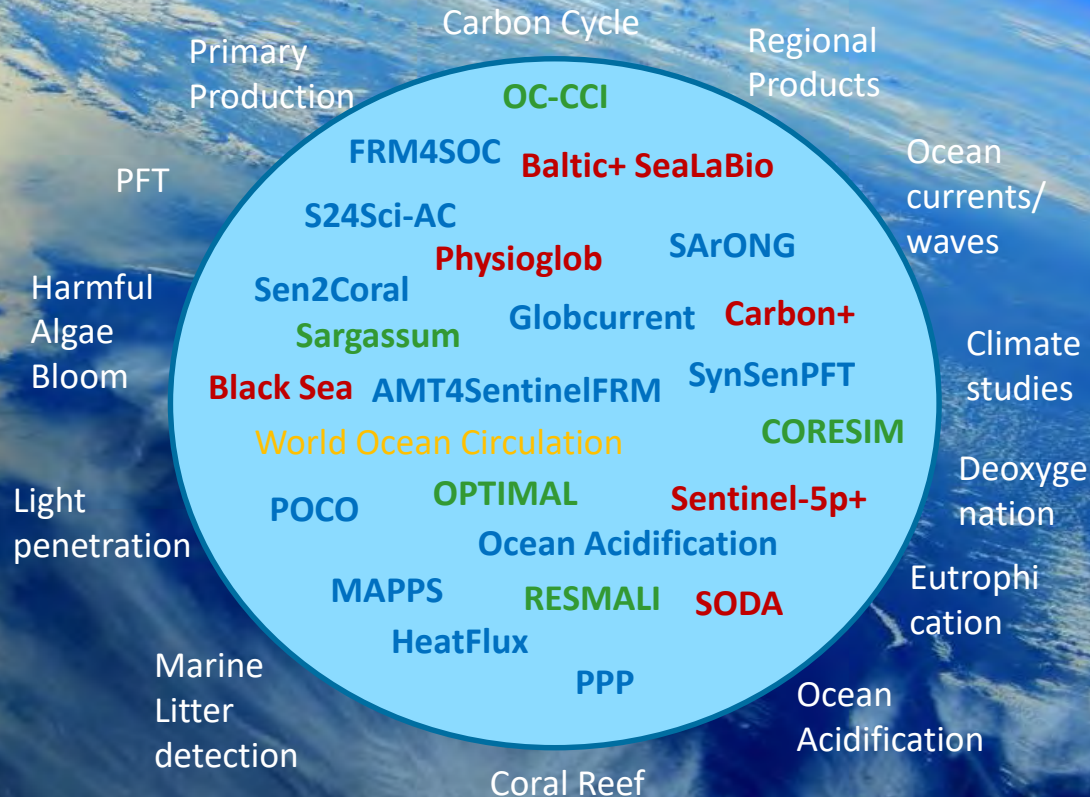
European Space Agency

- Further exploit the high resolution capability of existing EO measurements, **including OC**, to advance our knowledge in ocean currents and further foster users uptake of ocean currents products.
- ITT to be launched in 2019



# Emerging Applications and Science from ESA

Past Projects Running Projects Just started Projects In preparation Topic





# Meeting IOCS Recommendations?



## New Sensors/Capabilities

- Enhanced CALIOP sensor
  - Hyperspectral (2)
- Multi-sensor coastal & inland mission(s)
- Phycoerythrin bands @ high res
- Integrated EO, autonomous obs & modelling around earth system questions

## Algorithms, Products & Uptake

- Multi-water alg drive (2)
- Ocean carbon products
  - value and uptake
    - Big data for hyperspectral

## Assessment of Value & Impact

### Better translation into agency actions

## Improved Atmospheric Corrections

- Coastal & Inland (3)
- Trichodesmium apps

## In situ & Validation

- Improved validation efforts & better uncertainties
- Phyto community measurements & metrics

## Community Knowledge

- Trichodesmium protocols
- Radiometric protocols
- Inland & coastal protocols
- Algorithm performance metrics

## Infrastructure

- Resources for sustainable vicarious calibration

## Capacity Building

- Vicarious Calibration
- Better integrated approach with more opportunities



### New Sensors/Capabilities

- Enhanced CALIOP sensor
  - Hyperspectral (2)
- Multi-sensor coastal & inland mission(s)
- Phycoerythrin bands @ high res
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Thank you!

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- Vicarious Calibration
- Better integrated approach with more opportunities

Litter detection

Eutrophication

Validation

Integration