Downscaling of PHYSAT-Med to detect phytoplankton groups in the oligotrophic waters of Corsica (NW Mediterranean Sea)

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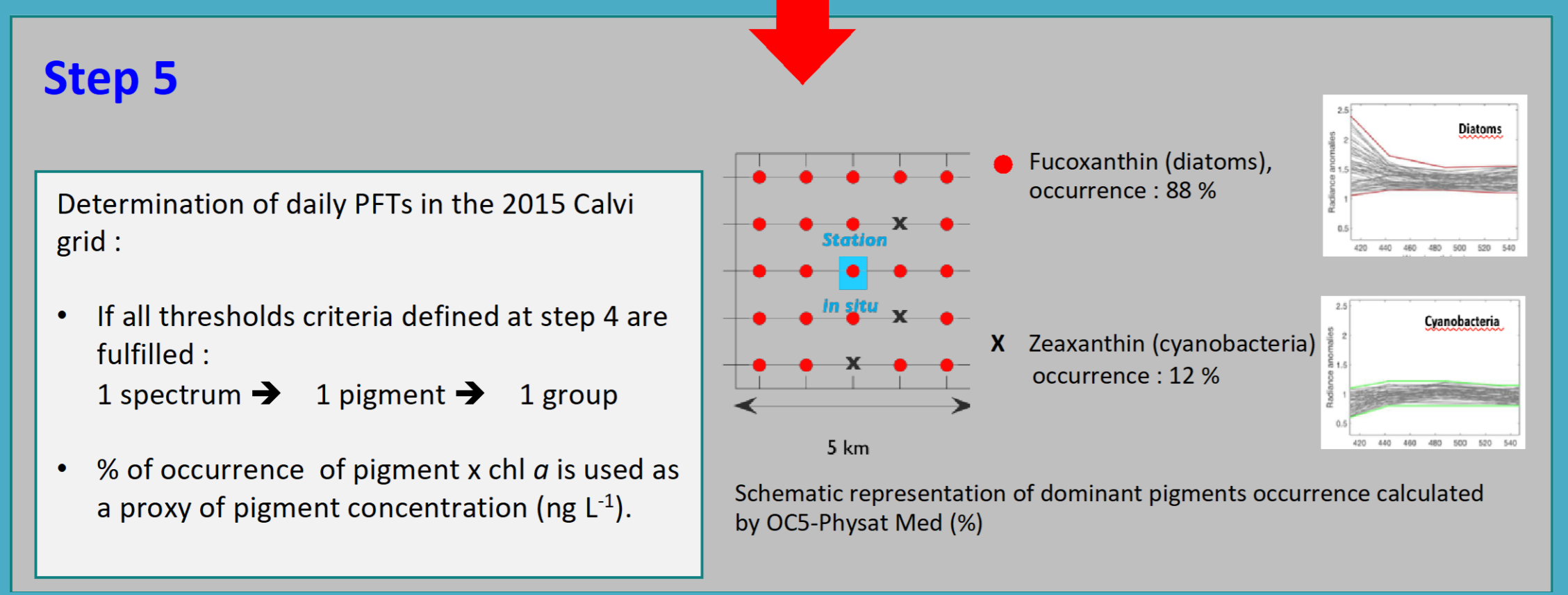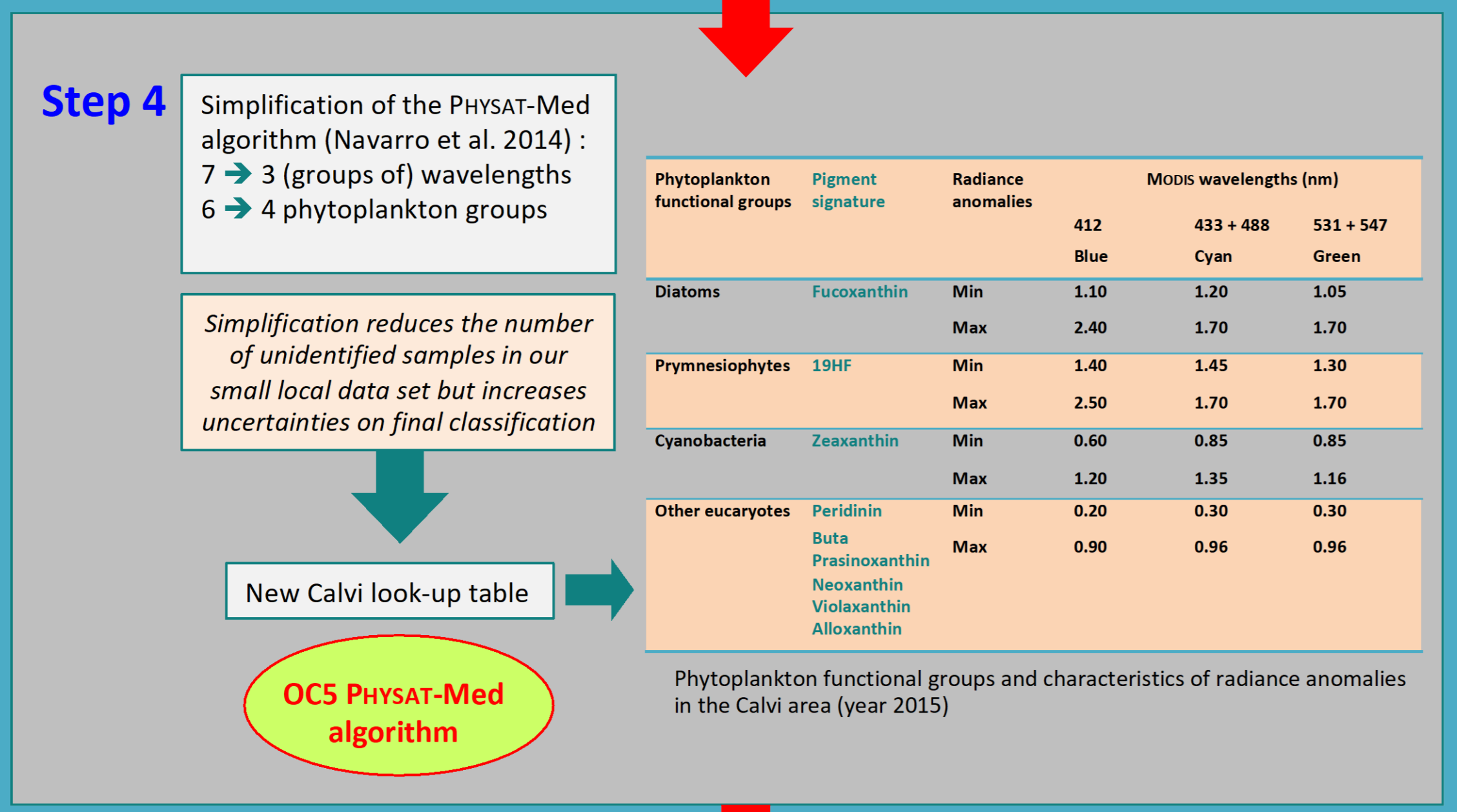[1] University of Liège, Belgium, A.Goffart@uliege.be [2] Ifremer, France, Sylvain.Coudray@ifremer.fr
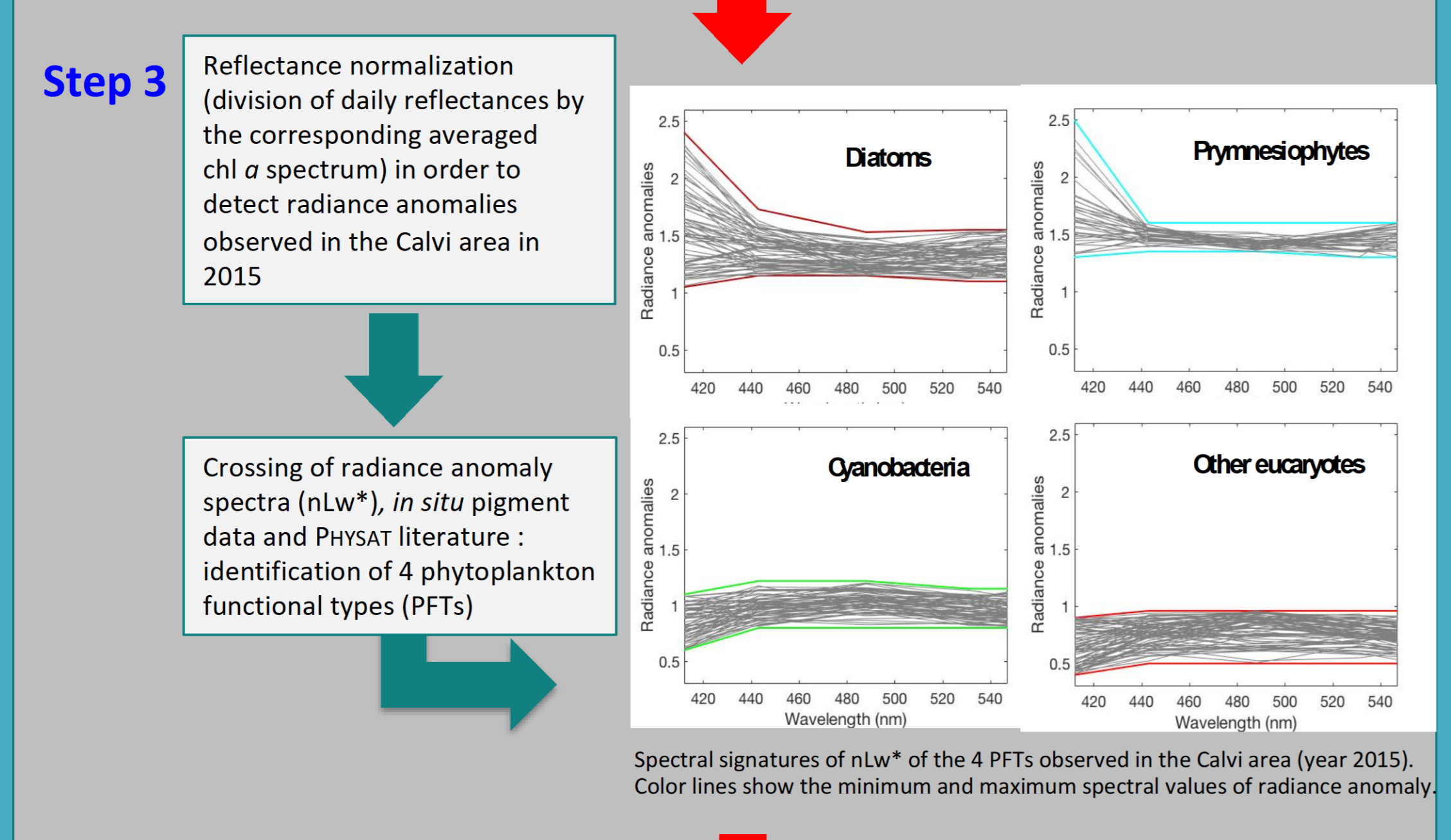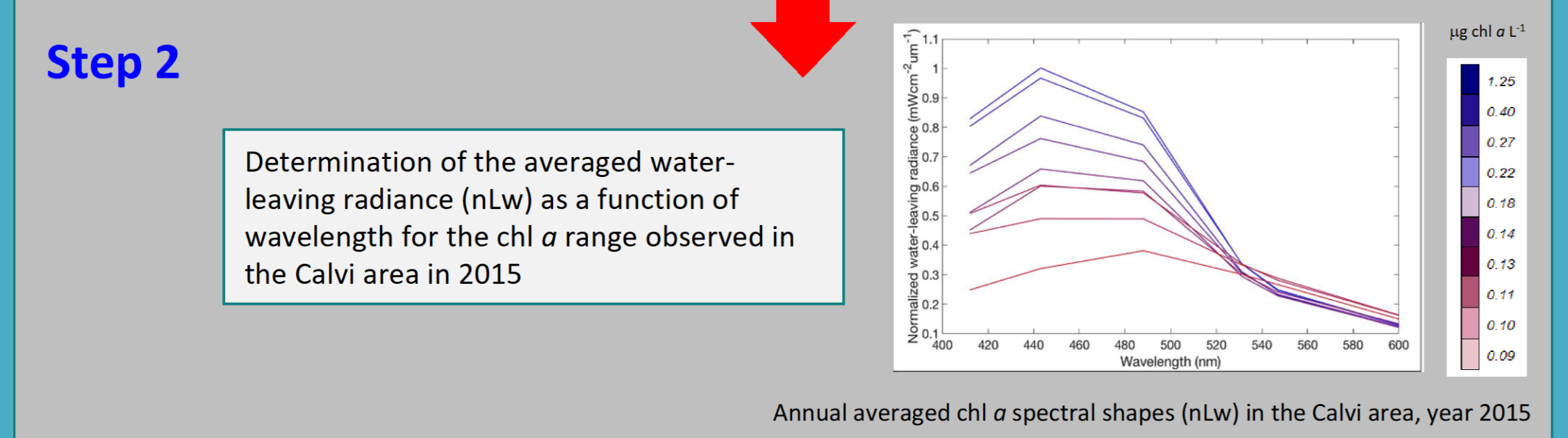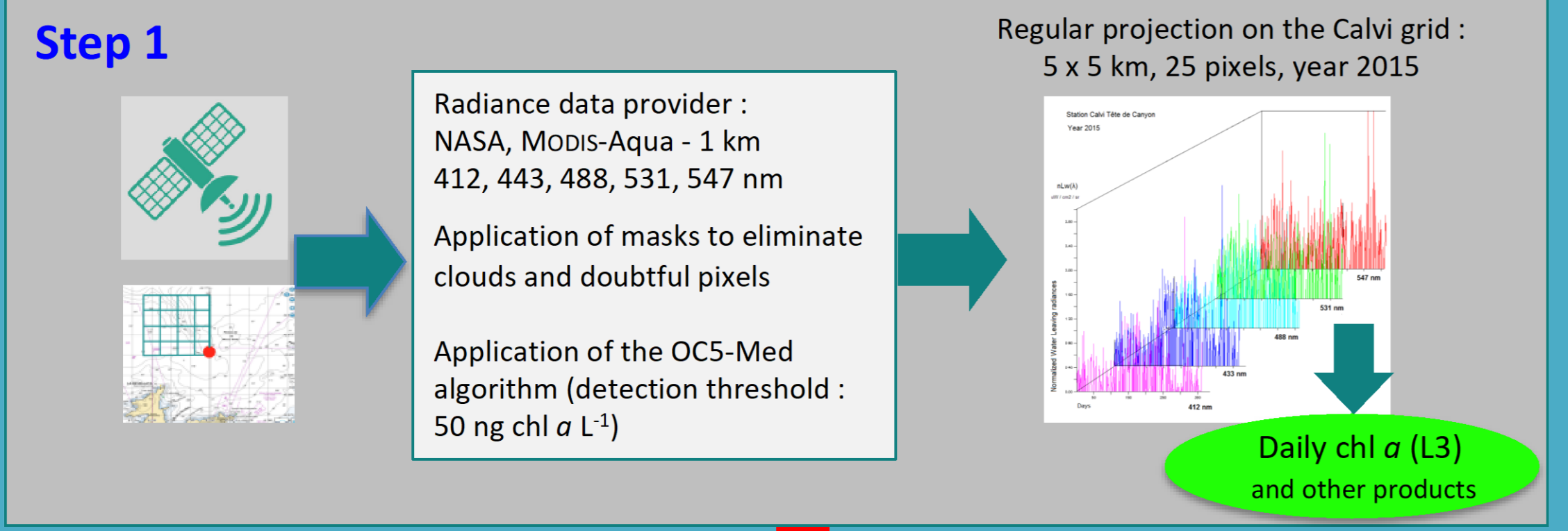
Abstract

In the Mediterranean Sea, satellite-derived chlorophyll *a* is largely used as a proxy for total surface phytoplankton biomass. The PHYSAT-Med algorithm (Navarro et al. 2014, 2017), based on analysis of radiance anomaly spectra, allows the detection of the six dominant phytoplankton groups in the whole basin.

In contrast, the algorithm development over dynamical and heterogeneous coastal and shelf waters is still not mature enough to be applied routinely as it is currently in offshore waters (Loisel et al. 2013).
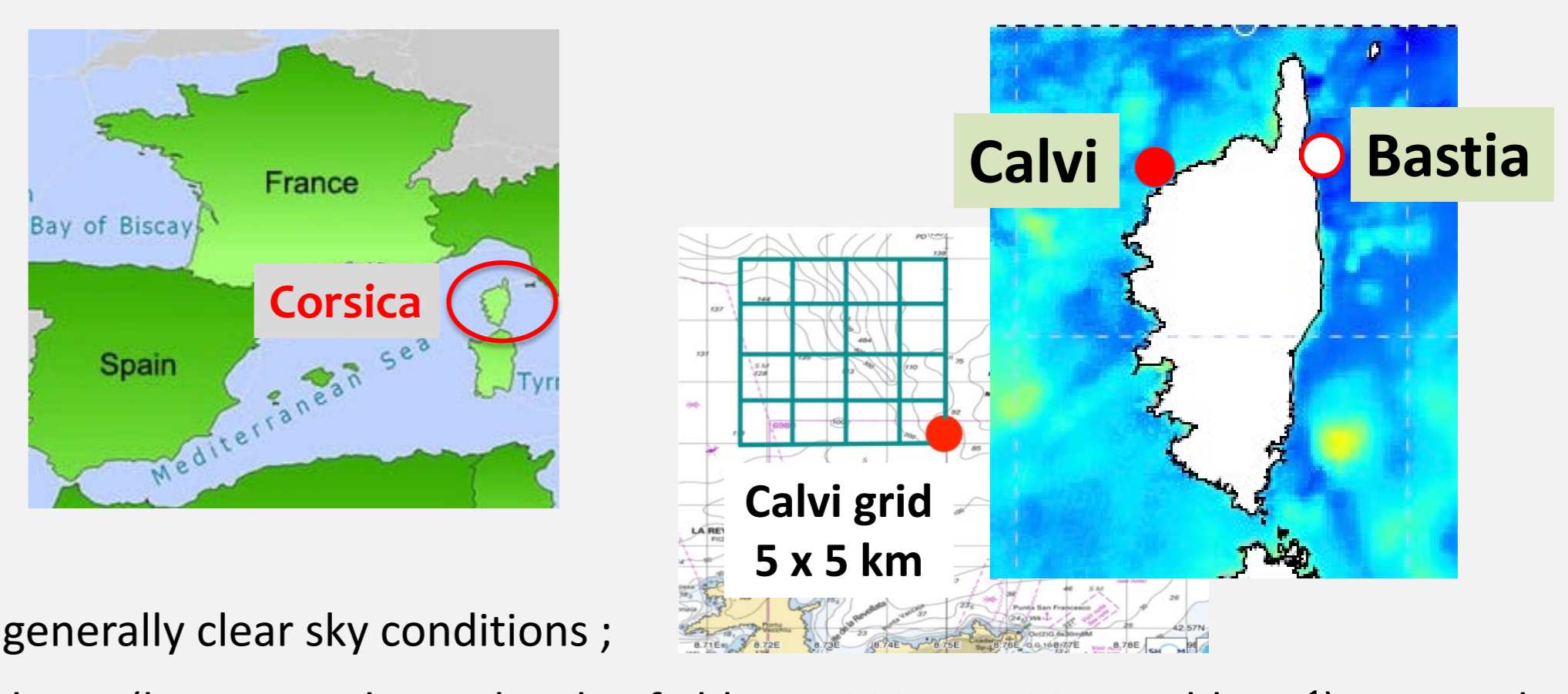
Here we present an adaptation of the PHYSAT-Med method to small-scale coastal and shelf areas of Corsica, generally characterized by oligotrophic waters and clear sky conditions. The downscaled method, referred as OC5-PHYSAT-Med, has been calibrated using one year of MODIS-Aqua data acquired off Calvi (Ligurian Sea) in a grid of 5 x 5 km and *in situ* pigment inventories acquired at a fixed station situated in the grid. Then, OC5-PHYSAT-Med has been validated with a pluriannual data set of *in situ* pigment concentrations acquired weekly at the Calvi station and monthly at the Bastia station (Tyrrhenian Sea).

The OC5-PHYSAT-Med reproduces satisfactorily the weekly and monthly variations of dominant phytoplankton groups (prymnesiophytes, cyanobacteria, diatoms), identified by their pigment signature. Quantification of « other eucaryotes » need to be improved. This suggests that OC5 PHYSAT-MED will increase our capacities to monitor phytoplankton in the Mediterranean Sea as required by two European Union's ambitious directives (Water Framework Directive and Marine Strategy Framework Directive) and to track potential signs of changes.

Downscaling of PHYSAT-Med

Step 1

Radiance data provider : NASA, MODIS-Aqua - 1 km 412, 443, 488, 531, 547 nm

Application of masks to eliminate clouds and doubtful pixels

Application of the OC5-Med algorithm (detection threshold : 50 ng chl *a* L^{-1})

Regular projection on the Calvi grid : 5 x 5 km, 25 pixels, year 2015

Daily chl *a* (L3) and other products

Step 2

Determination of the averaged water-leaving radiance (nLw) as a function of wavelength for the chl *a* range observed in the Calvi area in 2015

Annual averaged chl *a* spectral shapes (nLw) in the Calvi area, year 2015

Step 3

Reflectance normalization (division of daily reflectances by the corresponding averaged chl *a* spectrum) in order to detect radiance anomalies observed in the Calvi area in 2015

Crossing of radiance anomaly spectra (nLw*), *in situ* pigment data and PHYSAT literature : identification of 4 phytoplankton functional types (PFTs)

Diatoms / Prymnesiophytes / Cyanobacteria / Other eucaryotes

Spectral signatures of nLw* of the 4 PFTs observed in the Calvi area (year 2015). Color lines show the minimum and maximum spectral values of radiance anomaly.

Step 4

Simplification of the PHYSAT-Med algorithm (Navarro et al. 2014) : 7 ➜ 3 (groups of) wavelengths 6 ➜ 4 phytoplankton groups

Simplification reduces the number of unidentified samples in our small local data set but increases uncertainties on final classification

New Calvi look-up table

OC5 PHYSAT-Med algorithm

Phytoplankton functional groups	Pigment signature	Radiance anomalies	MODIS wavelengths (nm)		
			412 Blue	433 + 488 Cyan	531 + 547 Green
Diatoms	Fucoxanthin	Min	1.10	1.20	1.05
		Max	2.40	1.70	1.70
Prymnesiophytes	19HF	Min	1.40	1.45	1.30
		Max	2.50	1.70	1.70
Cyanobacteria	Zeaxanthin	Min	0.60	0.85	0.85
		Max	1.20	1.35	1.16
Other eucaryotes	Peridinin Buta Prasinoxanthin Neoxanthin Violaxanthin Alloxanthin	Min	0.20	0.30	0.30
		Max	0.90	0.96	0.96

Phytoplankton functional groups and characteristics of radiance anomalies in the Calvi area (year 2015)

Step 5

Determination of daily PFTs in the 2015 Calvi grid :

• If all thresholds criteria defined at step 4 are fulfilled : 1 spectrum ➜ 1 pigment ➜ 1 group

• % of occurrence of pigment x chl *a* is used as a proxy for pigment concentration (ng L^{-1}).

● Fucoxanthin (diatoms), occurrence : 88 %
X Zeaxanthin (cyanobacteria) occurrence : 12 %

Schematic representation of dominant pigments occurrence calculated by OC5-Physat Med (%)

Region of interest : Corsica

France / Bay of Biscay / Spain / Corsica / Mediterranean Sea
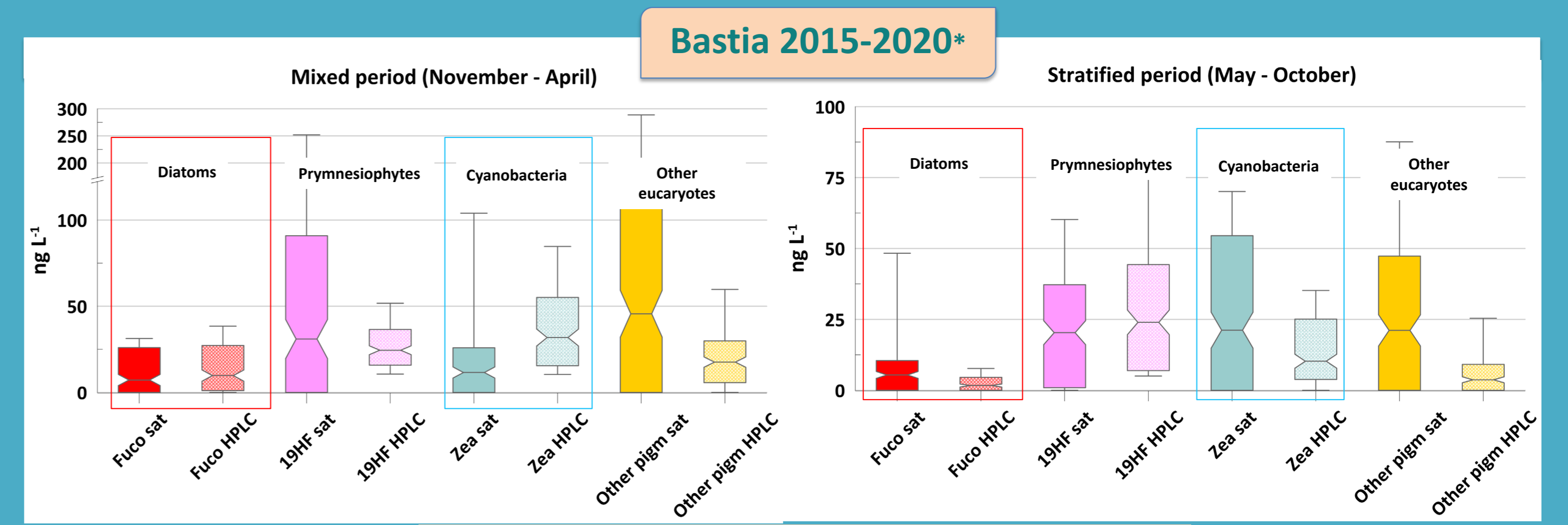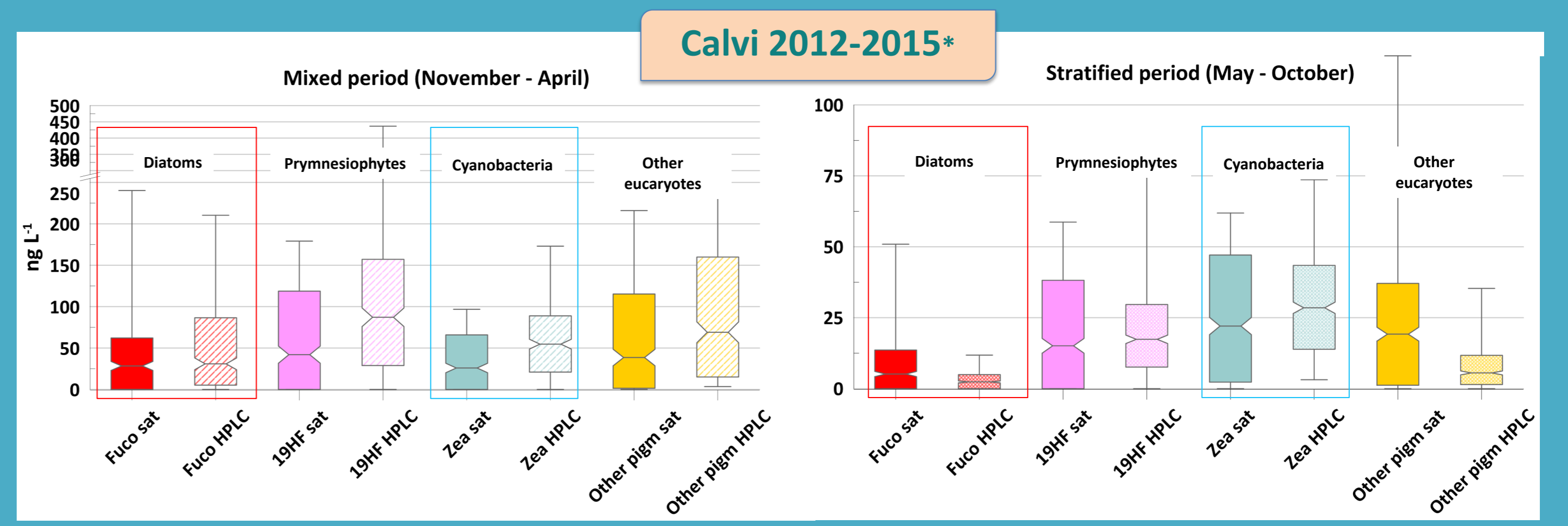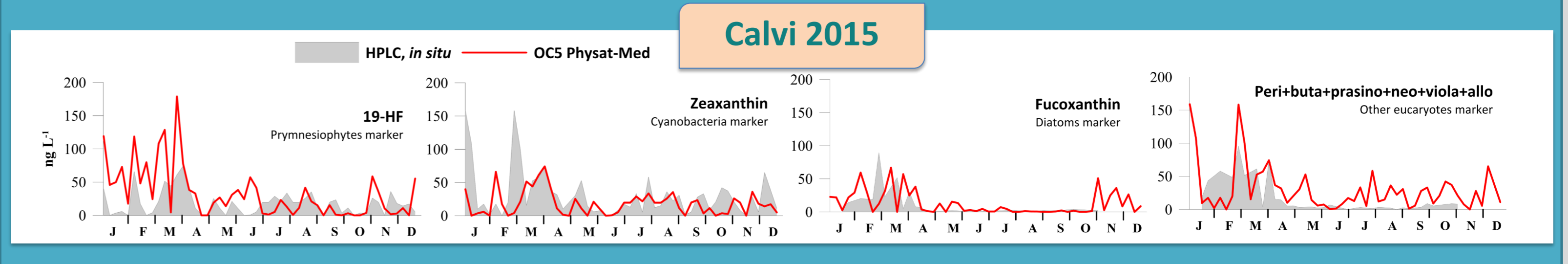
Calvi / Bastia

Calvi grid 5 x 5 km

• Oligotrophic waters and generally clear sky conditions ;
• Surface winter - spring bloom (low to moderate levels of chl *a*, ≈ 300 - 1 500 ng Tchl *a* L^{-1}) + DCM during the stratified period ;
• Most abundant phytoplankton groups, identified by their pigment signature : prymnesiophytes (19-HF), cyanobacteria (zeaxanthin) and diatoms (fucoxanthin), with a marked seasonality ;
• Time-series of *in situ* HPLC pigments at 2 stations : Calvi, Ligurian Sea, weekly sampling, 2012-2015, 150 m deep and Bastia, Tyrrhenian Sea, monthly sampling, 2015-2020, 40 m deep.

Results & perspectives

OC5 PHYSAT-Med reproduces satisfactorily the weekly and monthly variations of the 3 dominant phytoplankton functional types (PFTs), identified by their pigment signature, namely prymnesiophytes, cyanobacteria and diatoms.

Differences in spatial and temporal scales (OC5 PHYSAT-Med : data averaged weekly over a 25 km^2 grid, HPLC : 1 sample per week/month at a fixed station), cloud cover and downscaling uncertainties could explain the observed differences.

Quantification of « other eucaryotes » is less robust compared to other groups.

Comparison *of in situ* et OC5 PHYSAT-Med derived pigment concentrations

HPLC, *in situ* ▬ OC5 Physat-Med

Calvi 2015

19-HF Prymnesiophytes marker / Zeaxanthin Cyanobacteria marker / Fucoxanthin Diatoms marker / Peri+buta+prasino+neo+viola+allo Other eucaryotes marker

Calvi 2012-2015*

Mixed period (November - April) / Stratified period (May - October)

Diatoms / Prymnesiophytes / Cyanobacteria / Other eucaryotes

Fuco sat / Fuco HPLC / 19HF sat / 19HF HPLC / Zea sat / Zea HPLC / Other pigm sat / Other pigm HPLC

Bastia 2015-2020*

Mixed period (November - April) / Stratified period (May - October)

Diatoms / Prymnesiophytes / Cyanobacteria / Other eucaryotes

Fuco sat / Fuco HPLC / 19HF sat / 19HF HPLC / Zea sat / Zea HPLC / Other pigm sat / Other pigm HPLC

*In situ pigments and satellite imagery data acquired in the same weeks

Further developments of OC5 PHYSAT-Med should focus on :
• the reduction of uncertainties in the detection of the dominant phytoplankton groups by OC5 PHYSAT-Med (*e.g.* by using Sentinel 3-OLCI data);
• the quantification improvement of the « other eucaryotes » group.

Loisel et al. (2013) In « Topics in Oceanography » Enrico Zambianchi Ed.
Navarro G et al. (2014) Remote Sensing of Environment 152 : 557-575
Navarro G et al. (2017) Frontiers in Marine Science 4