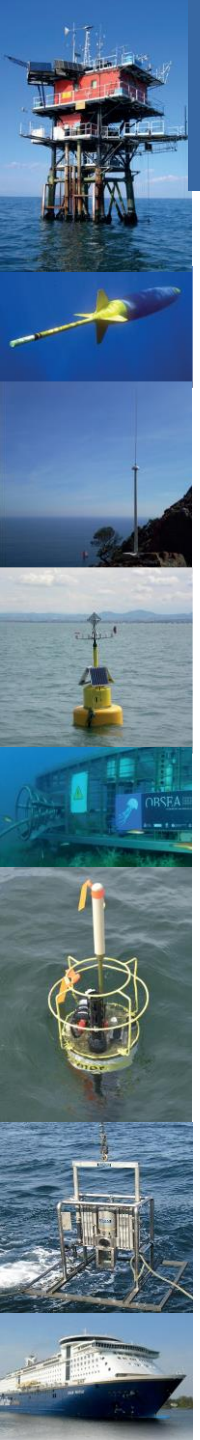


9th EuroGOOS International Conference
Advances in Operational Oceanography: Expanding Europe's ocean observing and forecasting capacity

Phytoplankton *in vivo*/*in situ* observations by novel automated optical approaches in coastal and marine systems: towards a better integration into joint observatories

Luis Felipe ARTIGAS (felipe.artigas@univ-littoral.fr)

Laboratory of Oceanology and Geosciences (LOG) CNRS UMR 8187 LOG-Univ Littoral Côte d'Opale-Univ. Lille, Wimereux, France

Créach, V., Cabrera, P., Claquin, P., Gallot, C., Gómez, F., de Blok, R., Bigand A., Debusschere, E., Deneudt, K., Grassi K., Grégori, G., Eikrem, W., Epinoux, A., Hébert P.-A., Haraguchi, L., Hubert, Z., Houliez, E., Irisson, J.-O., Karlson, B., Kraft, K., Kromkamp, J., Lindh, M., Lefebvre, A., Lombard, F., Lizon, F., Louchart, A., Möller, K.O., Mortelmans, J., Poisson-Caillault, E., Rijkeboer, M., Rutten, T., Tamminen, T., Tyberghein, L., Thyssen, M., Ruhel, S., Seppälä, J., Stemmann, L., Veen, A., Wacquet, G., Wollschläger, J., Ylöstalo, P.

Phytoplankton (EOV) monitoring challenges

As changes in **phytoplankton abundance, biomass and composition** usually occur at **short-time and fine spatial scales**, there is an increasing need for using **high resolution sensors** which could be implemented in **autonomous platforms** (buoys, automated stations, research vessels, ships of opportunity) integrated into standard, advances or supersite observatories (proofs of concept)

Critical gaps :

- lack of definition of the **most appropriate methodologies** and approaches (platforms)
- deficiencies in the **spatio-temporal distribution of observations**
- not adopting **FAIR principles in data distribution**, including using adequate QA/QC measures

An **international network of experts is essential to work on** :

- best suitable **combination of *in vivo* automated sensors** for each marine system considered
- harmonizing operational practices for defining common **best practices**
- **defining common vocabulary** and data quality control, **data charts & flows**

*National and regional marine & coastal programmes in Europe, including past projects INTERREG IVA « 2 Seas » **DYMAPHY** (2010-2014), H2020 **JERICO-Next** (2015-2019) & ongoing projects CPER **MARCO** (2016-2021), **JERICO S3** (Science, Service, Sustainability - 2020-2024), **JERICO DS,** amongst others, for building the **JERICO RI.***

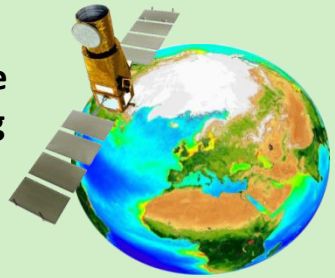
Phytoplankton observation

Research / Opportunity Vessels

Moorings

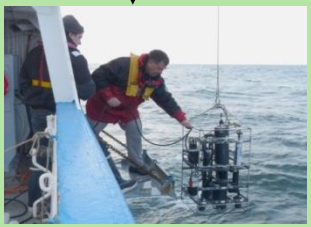
Gliders

Remote sensing



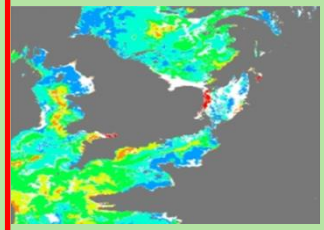
Monitoring strategy

Discrete sampling



Profiles

Continuous pumping/recording



Synoptic/regional

Sampling strategy

At the laboratory/ On board

Real time

Real time

Real time

Analysis

Microscopy
Pigment analysis
Total/Spectral Fluorometry
Flow cytometry
Image Analysis
Molecular tools

In vivo Total/Spectral Fluorometry
Optic probes
Automated Flow cytometry
Image Analysis

In vivo Total/spectral Fluorometry
Automated Flow cytometry
Image Analysis
Molecular tools

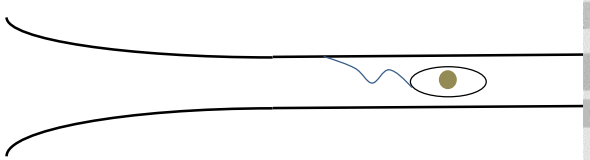
Ocean optics from satellites
Development of new Algorithms
Comparison with *in situ* data

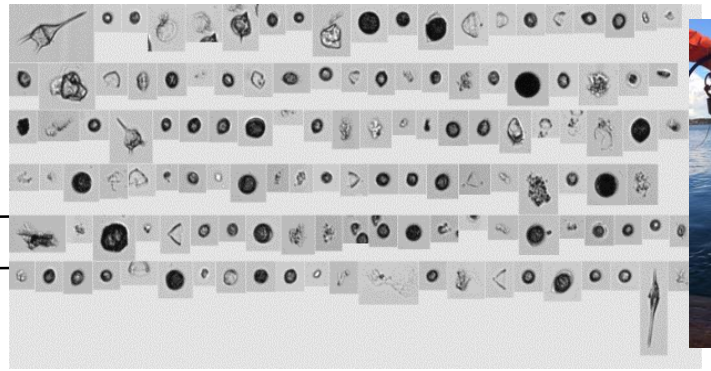
Techniques

www.dymaphy.eu

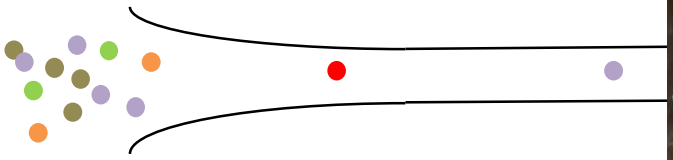
In vivo/in situ automated techniques for monitoring phytoplankton

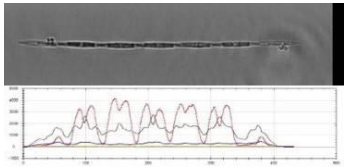
Imaging/in flow
Single cell-size and morphology
of organisms: taxa

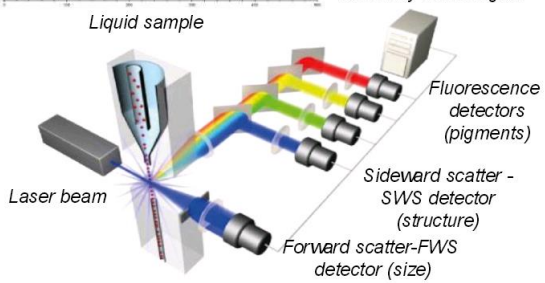




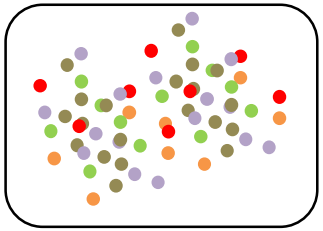
Automated flow cytometry (pulse shape-recording)
Single cell-fluorescence – pigment content and scattering
(size, shape): functional groups

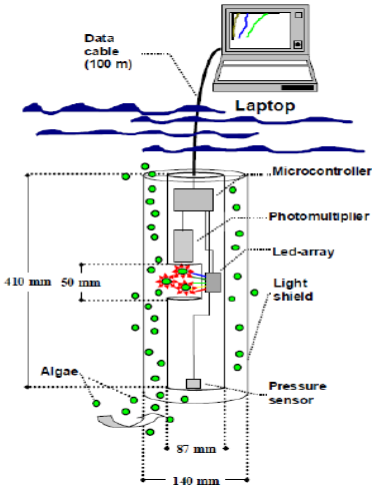


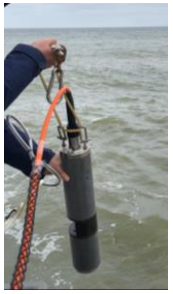


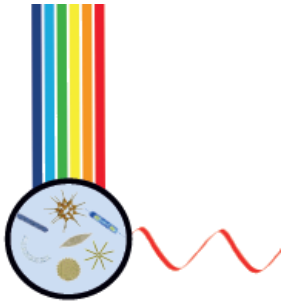


Fluorescence and absorption (multi-spectral)
Pigment based methods – bulk properties – pigmentary groups
Variable (active) fluorescence :
photosynthetic parameters, primary productivity



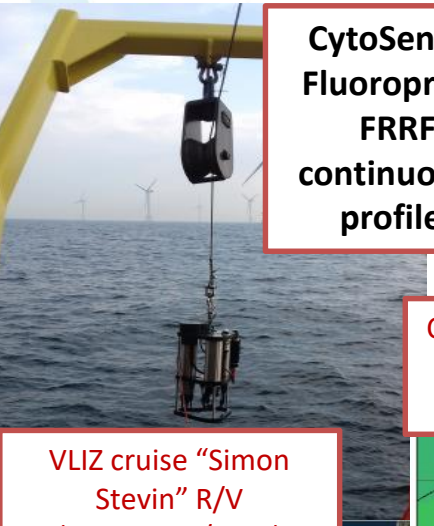






Platforms for phytoplankton automated observation

JERICO RI
SCIENCE - SERVICES - SUSTAINABILITY

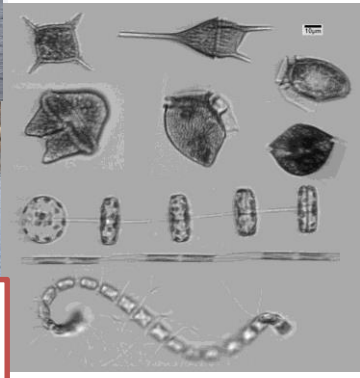


CytoSense– Fluoroprobe FRRF continuous + profiler

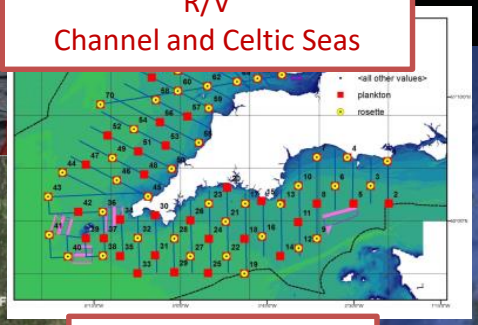
Fluorometer + FRRF

Ifremer/CNRS-BOREA
Smile Buoy
Bay of Seine

Fluorometers, Imaging Cytobot



Cefas cruises « Endeavour » R/V
Channel and Celtic Seas



SMHI Tangesund observatory Skagerrak

VLIZ cruise “Simon Stevin” R/V (CNRS-LOG/RWS)
SW North Sea

FB + CytoSense

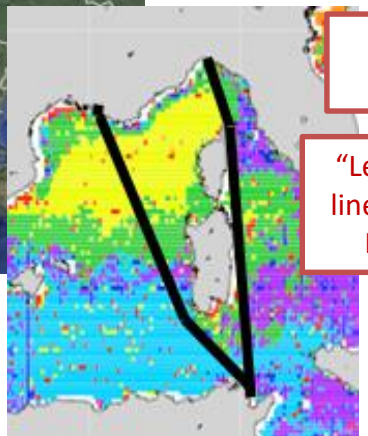
Some field implementation within JERICO-NEXT (May 2016-August 2018)

ETOILE cruise “Côtes de la Manche” R/V
Bay of Biscay
IFREMER/AZTI/CNRS LOG

Fluoroprobe CytoSense

PhytoPAM, CytoSense, AOA, FRRF

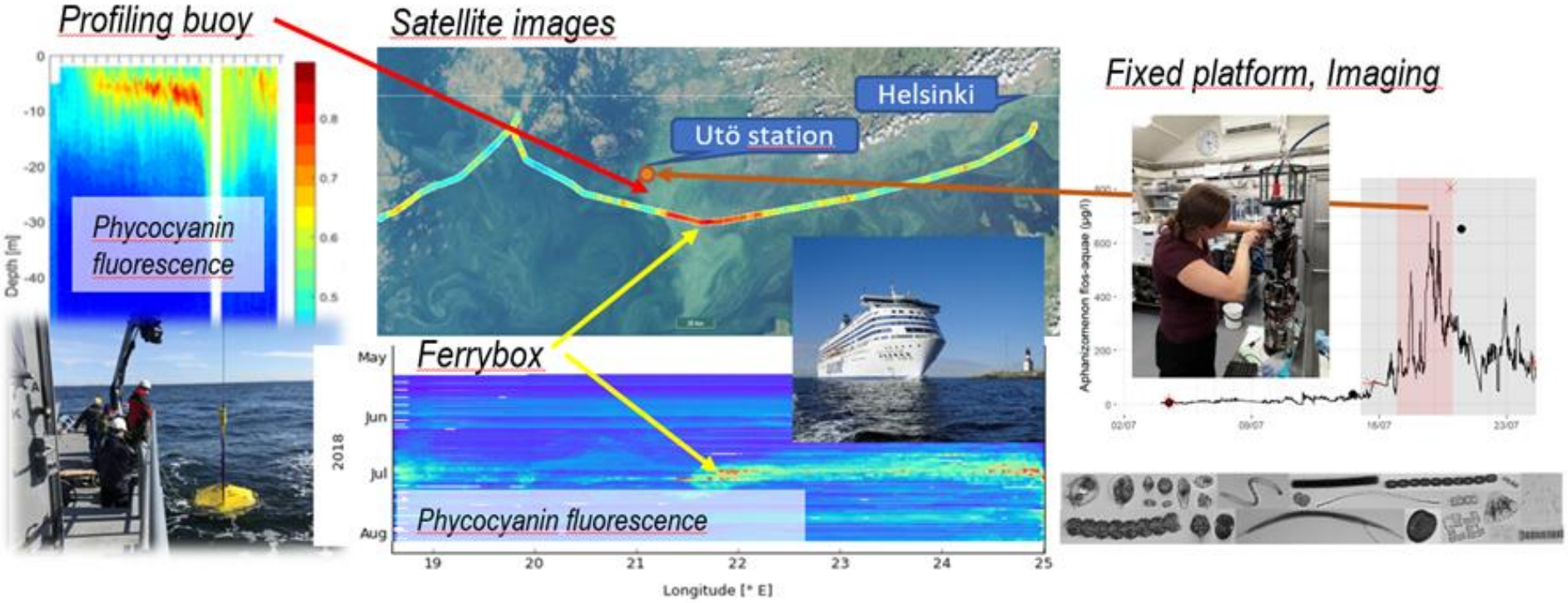
PHYCO cruise
“Côtes de la Manche” R/V
CNRS-LOG/IFREMER
Eastern English Channel



FB + pCO_2 + CytoSense

“Le Carthage” Ferry line CNRS-MIO - NW Mediterranean

Example of proof of concept: the Gulf of Finland Pilot Supersite



Regional, combined multiplatform observation to create data-products for phytoplankton

- *Imaging FlowCytobot, Cytosense, Pigment fluorescence, Fluorescence induction, Spectral absorption*
- *Development of near-real time analysis of image data*

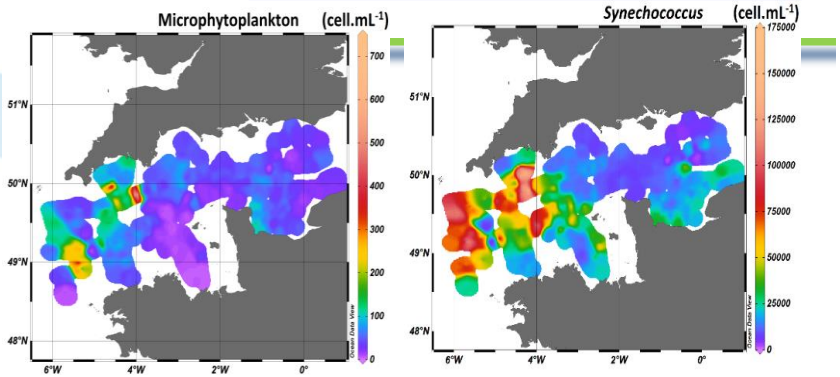
Harmonization of transnational observations

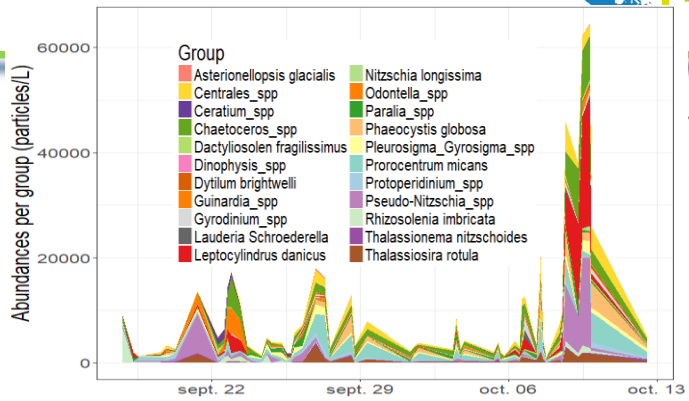
- *Joint workshops for calibration and best practices*

Kraft et al., 2021 – FMARS https://www.frontiersin.org/article/10.3389/fmars.2021.594144

Automated monitoring in the Channel-North Sea

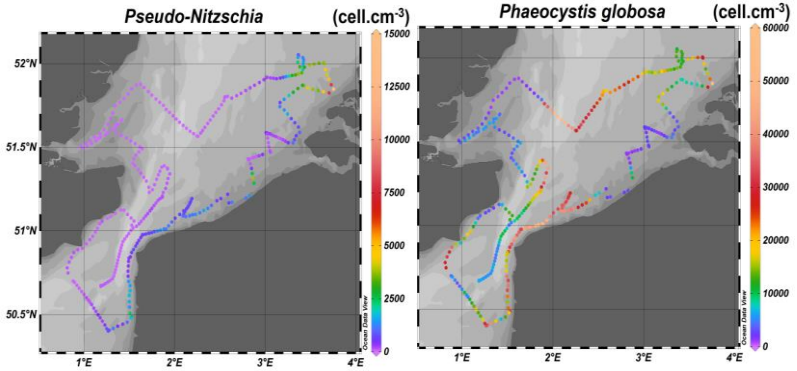
Louchart *et al.*, CSR 2020 - https://doi.org/10.1016/j.csr.2020.104056

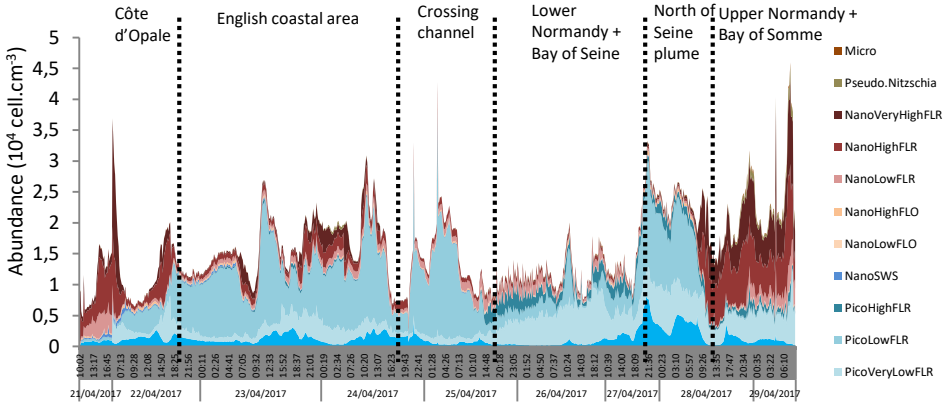


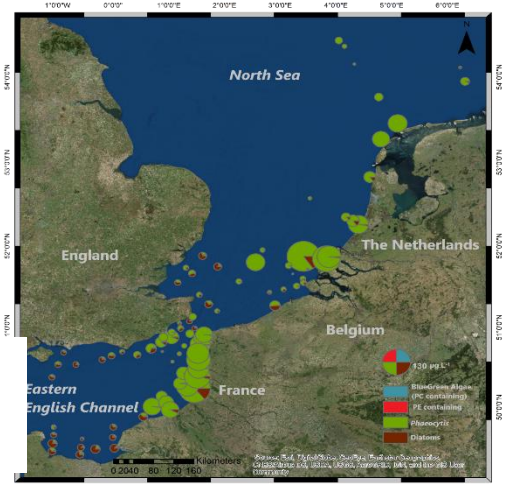


Wacquet *et al.*, 2020 (ICHA 2018)

Louchart, 2020 (PhD)

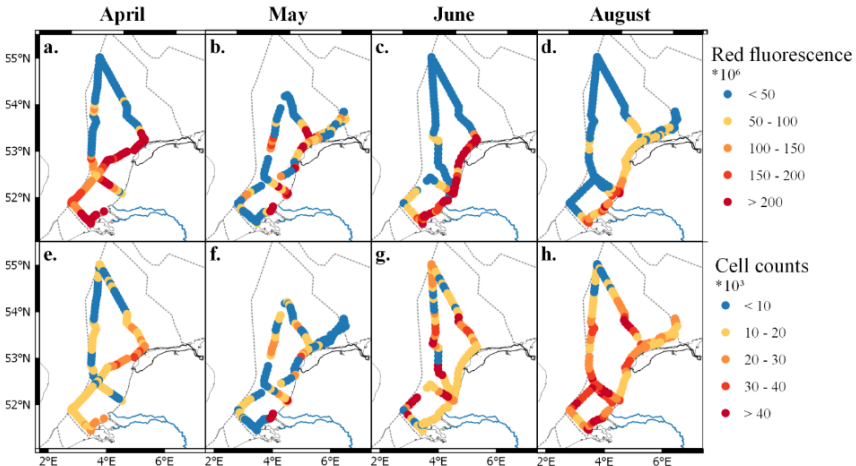




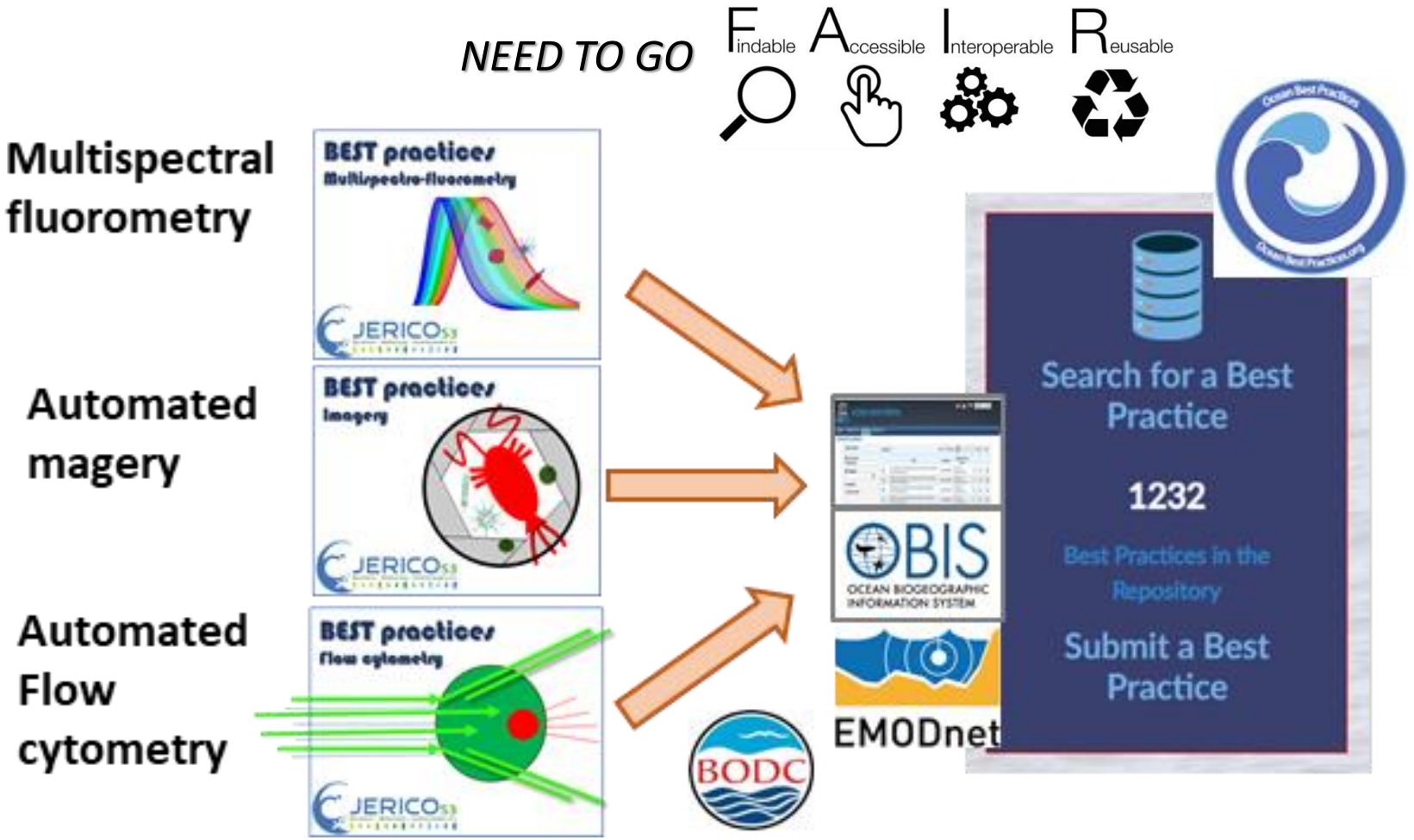


Louchart *et al.*, 2020 (ICHA 2018)

Aardema et al. 2019 Ocean Sci., 15, 1267–1285, 2019 https://doi.org/10.5194/os-15-1267-2019

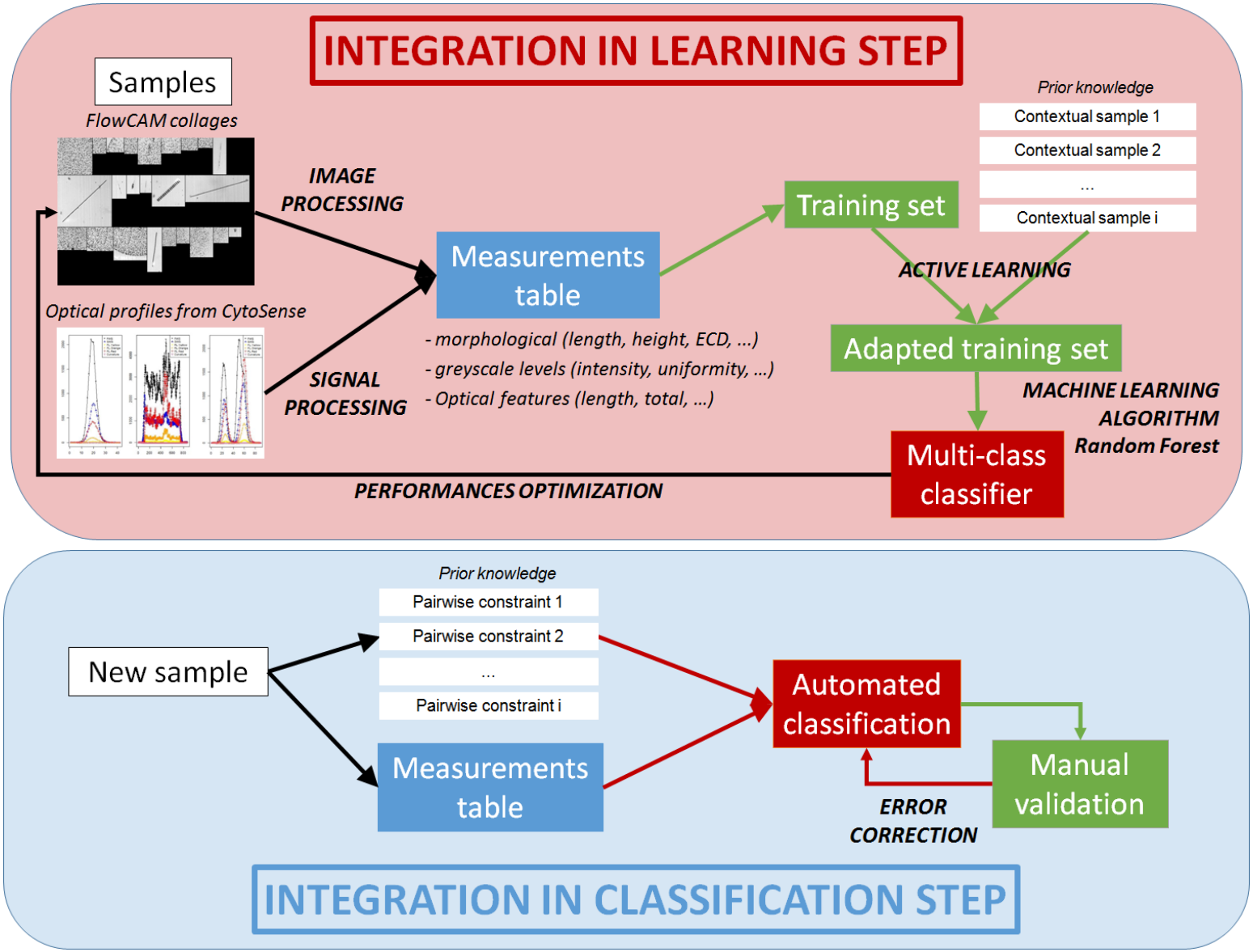


Integration, validation, archives and long-term accessibility of biological (plankton) data



Three questionnaires released on the www.jerico-ri.eu webpage

Towards automated analysis of phytoplankton images/optical profiles



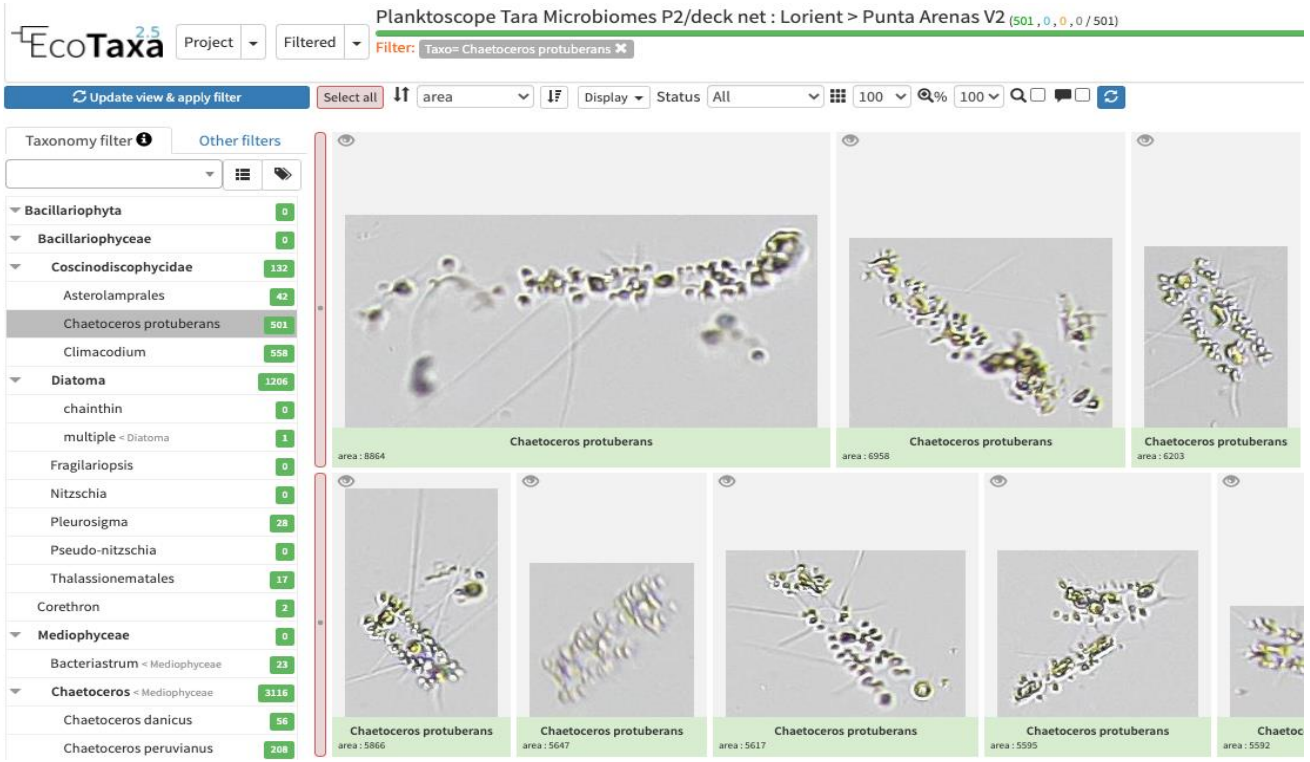
Wacquet *et al., 2020* (ICHA 2018)

Processing and storage of thousands of data (raw optical data, images and automated classification)

ZooPhytoImage (U Mons-Ifremer-CNRS/LOG), RClusToolBox (LISIC/ULCO-CNRS/LOG), UhMM (Ifremer-LISIC/ULCO) EasyClus (TRP), EMODNET, SeaDataNet, EcoTaxa, other tools…

ECOTAXA: A free collaborative tool for hosting, sorting, annotating taxonomically and sharing images.

- Explicit taxonomy
- Built-in automatic classification algorithms (random tree forest, CNN networks)

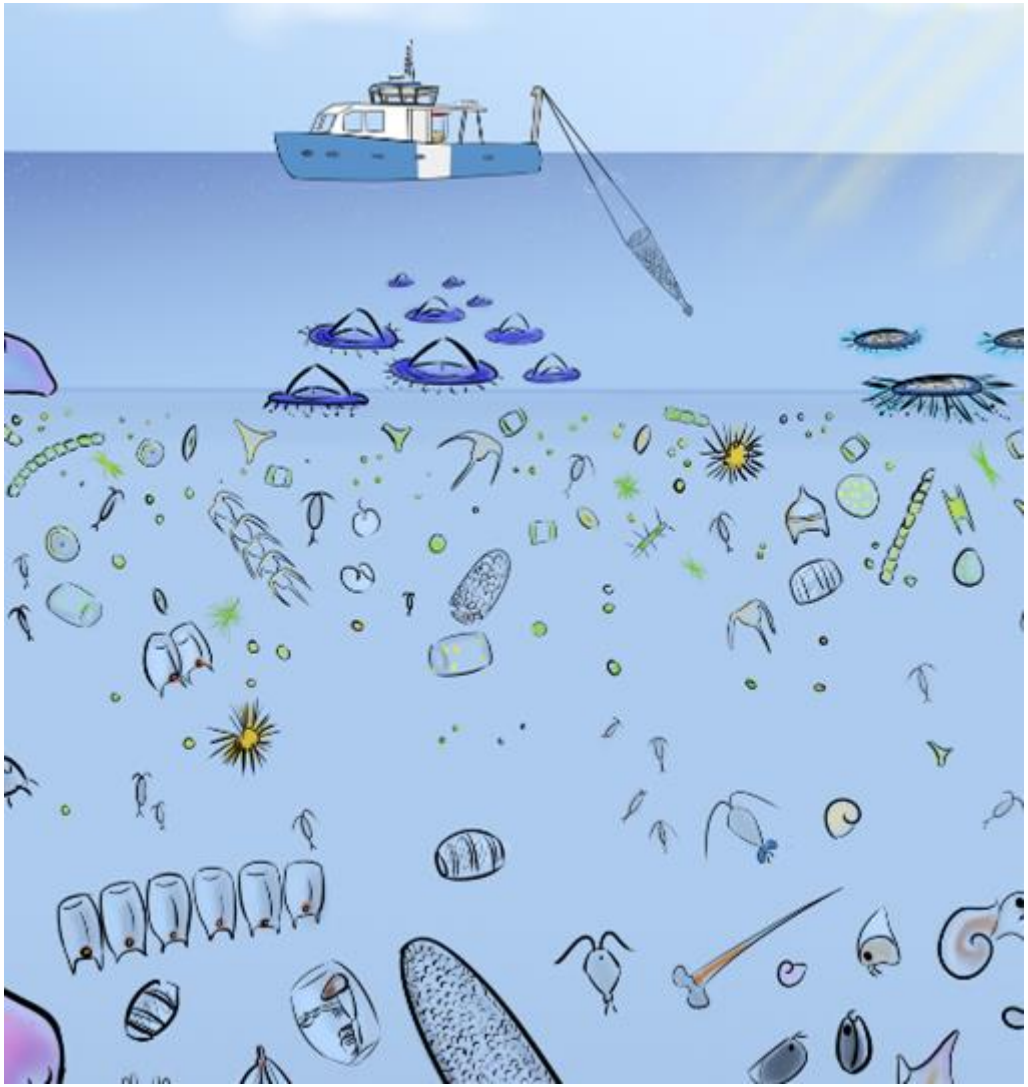


http://ecotaxa.obs-vlfr.fr/explore/

Picheral M., Stemman L., MMV 2017

Conclusion and perspectives

- Automated approaches provide **new insights into phytoplankton dynamics** at **fine spatial (horizontal and vertical) and temporal scales**
- Need to keep improving the **operability (procedures, best practices)** and related **discrimination (classification tools) capacity** of automated techniques addressing phytoplankton **dynamics & diversity** and **productivity**
- After implementing new **common vocabularies** per technique, **harmonizing metadata** and establishing **database formats,** we intend to establish **quality control annotations (QA/QC)** for the 3 approaches to use the data with confidence.
- Combining **high frequency biological data with physical and biogeochemical data** using complementary approaches is the key for an **integrated monitoring** and a better understanding of ecosystems changes.
- Better assessment of the **ecological meaning** of **new defined phytoplankton functional groups** and their contribution to primary productivity and biogeochemical cycles, for better integration into **models**, indicators, and **remote sensing products**
- Need to consider the **vertical component** of abundance, biomass, light and physiology in order to address properly the integrated **water column productivity** and the **pelagic-benthic coupling**



Thanks for your attention!

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