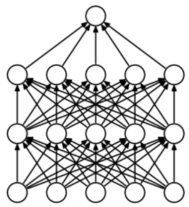
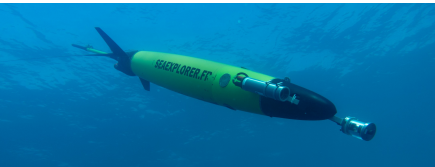
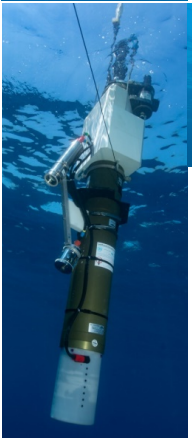
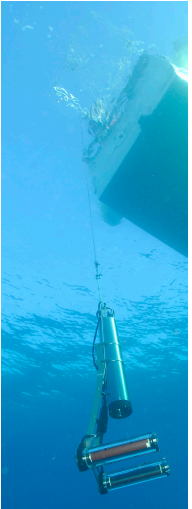
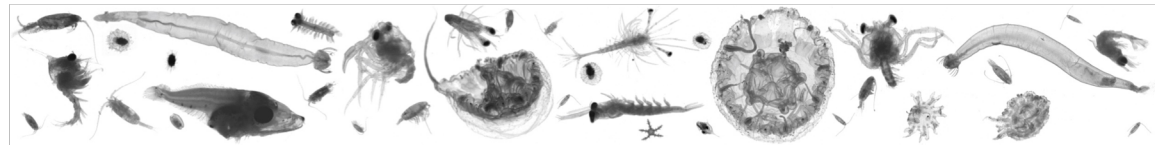


# Towards a coordinated global marine biodiversity observing system

## Towards a global *in situ* monitoring of plankton using imaging systems: lessons learnt from the past 10 years of observation in Europe



Lars Stemmann, Romagnan Jean Baptiste, Alain Lefebvre, Gérald Grégori, Jean Olivier Irisson, Bengt Karlson, Jukka Seppala, Kaisa Kraft, Guidi Lionel, Luis Felipe Artigas, Dodji Soviadan, Guillaume Wacquet, Klas Ove Möller, Klaas Deneudt, Simon Claus, Fabien Lombard



# Phytoplankton and Zooplankton abundance and diversity have been tagged as

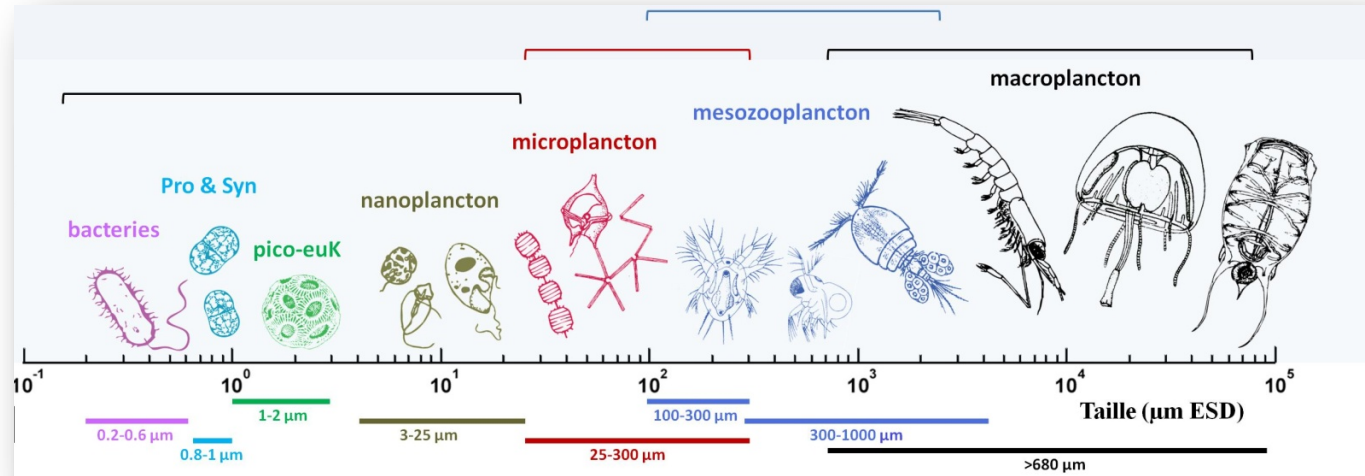
- **Ecosystem Essential Ocean Variables (eEOVs)** by GOOS (Global Ocean Observing System)
- **Essential Climate Variables (ECVs)** under GCOS (Global Climate Observing System)
- **Ecosystem Biodiversity Variable** (GEO BON, Group on earth observation)

The screenshot shows the front page of a research article on the Frontiers in Marine Science website. The article is titled "Globally Consistent Quantitative Observations of Planktonic Ecosystems" and is a review article published in Front. Mar. Sci. on 25 April 2019. The authors listed include Fabien Lombard, Emmanuel Boss, Anya M. Waite, Meike Vogt, Julia Uitz, Lars Stemmann, Heidi M. Sosik, Jan Schulz, Jean-Baptiste Romagnan, Marc Picheral, Jay Pearlman, Mark D. Ohman, Barbara Niehoff, Klas O. Möller, Patricia Miloslavich, Ana Lara-Lpez, Raphael Kudela, Rubens M. Lopes, Rainer Kiko, Lee Karp-Boss, Jules S. Jaffe, Morten H. Iversen, Jean-Olivier Irisson, Katja Fennel, Helena Hauss, Lionel Guidi, Gaby Gorsky, Sarah L. C. Giering, Peter Gaube, Scott Gallager, George Dubelaar, Robert K. Cowen, François Carlotti, Christian Briseño-Avena, Léo Berline, Kelly Benoit-Bird, Nicholas Bax, Sonia Batten, Sakina Dorothee Ayata, Luis Felipe Artigas, and Ward Appeltans. The article has received 2,528 total views and has an Altmetric score of 21. The page also features a "Check for updates" button, "Download Article" and "Export citation" options, and a "View Article Impact" button. The website header includes the Frontiers logo, the journal title "in Marine Science", and the section "Ocean Observation". A navigation bar at the top lists "SECTION", "ABOUT", "ARTICLES", "RESEARCH TOPICS", "FOR AUTHORS", and "EDITORIAL BOARD". A blue banner at the top right indicates "CITE SCORE" and "2018 edition".



# A whole suite of sea going and Lab imaging instruments

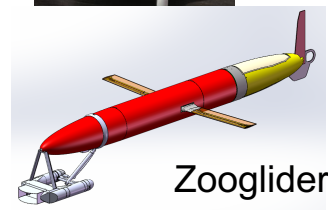
UVP6\*



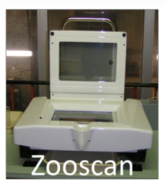
BOP



SOLOPC



Zooglider



Zooscan  
Zooscan\*



Flowcam  
Flowcam\*



SPC

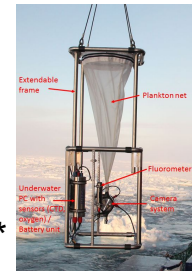


IFCB\*

Cytobuoy \*

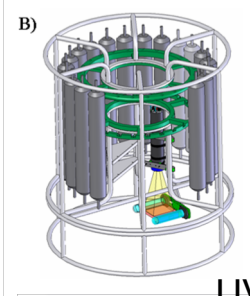


CPICS \*



LOKI\*

USP/Brasil



UVP5\*



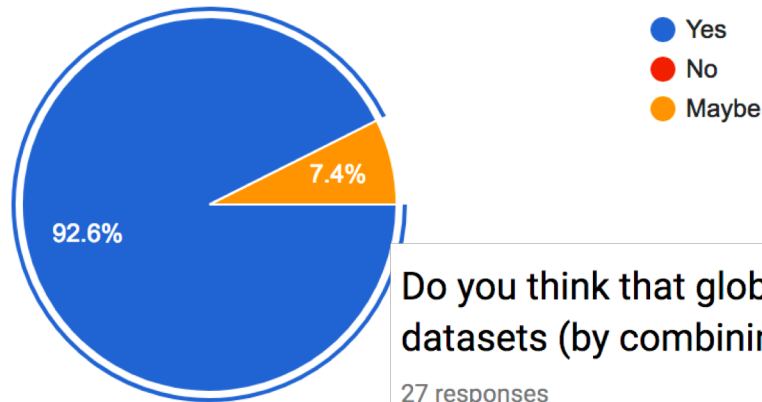
ISIS\*

\* Commercially available

# A whole suite of colleagues (mostly biologists) sharing the same ideas (May 2018)

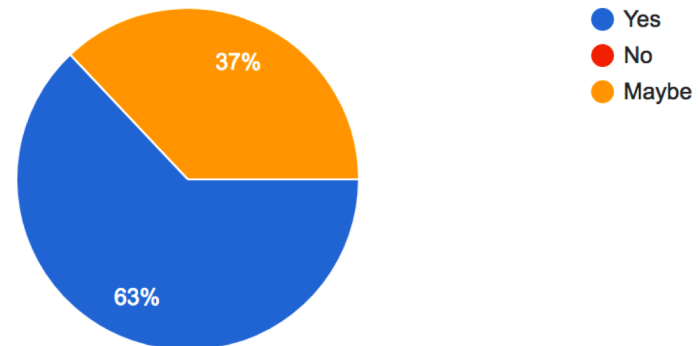
Do you think that collaborative ways to visualize, annotate, quality control, and share the resulting data is important ?

27 responses

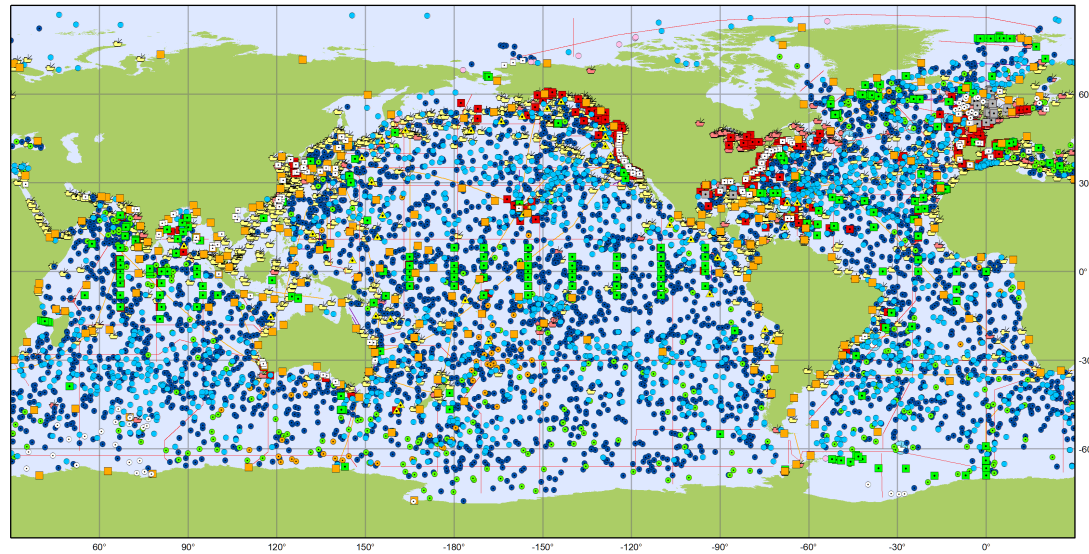


Do you think that global plankton datasets can emerge from local datasets (by combining regional results)

27 responses



# The 10 years vision, Plankton: global and regional monitoring with imaging systems



Main in situ Elements of the Global Ocean Observing System

April 2019

## Profiling Floats (Argo)

- Core (3880)
- Deep (79)
- BioGeoChemical (352)

## Data Buoys (DBCP)

- Surface Drifters (1444)
- Offshore Platforms (97)
- Ice Buoys (11)
- Moored Buoys (358)
- ▲ Tsunameters (38)

## Timeseries (OceanSITES)

- Interdisciplinary Moorings (351)

## Repeated Hydrography (GO-SHIP)

- Research Vessel Lines (62)

## Sea Level (GLOSS)

- Tide Gauges (252)

## Ship based Measurements (SOT)

- Automated Weather Stations (257)
- Manned Weather Stations (1324)
- Radiosondes (11)
- expendable BathyThermographs (34)

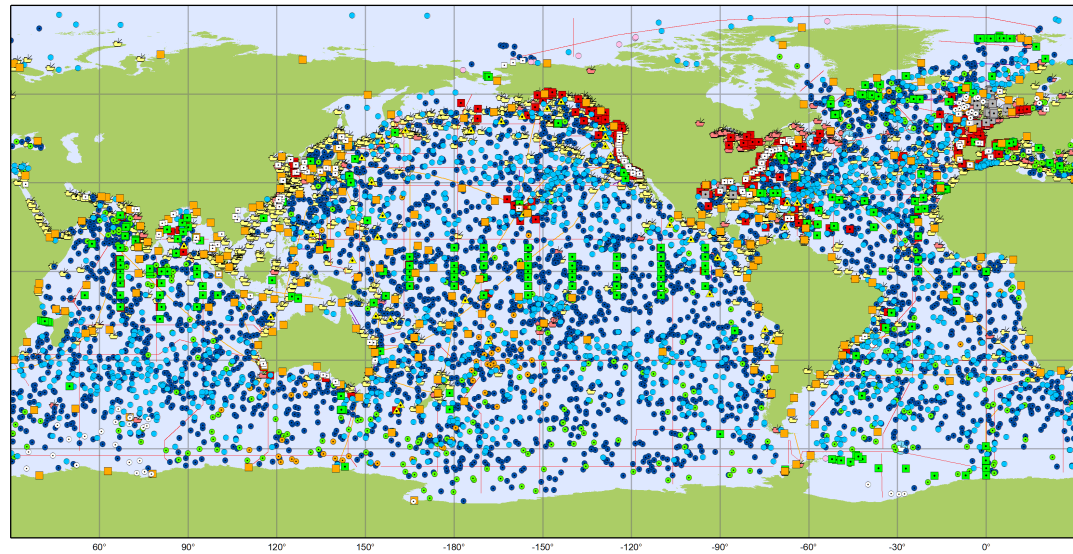
## Other Networks

- HF Radars (270)
- Animal Borne Sensors (53)
- Ocean Gliders (31)



Generated by [www.jcommaps.org](http://www.jcommaps.org), 14/05/2019

# The 10 years vision, Plankton: global and regional monitoring with imaging systems



Main in situ Elements of the Global Ocean Observing System

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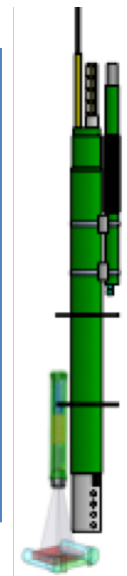
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Generated by [www.jcommaps.org](http://www.jcommaps.org), 14/05/2019

**-Ecosystem monitoring**

**- Data assimilation in models for carbone cycles and marine ressources.**



$D_{PSD}$

**Particulate Organic Carbon**

$Z_n$

**macro and mesoplankton  
(Taxa size spectra)**

$P_\lambda$

**Pico and microplankton  
(taxa, size spectra)**

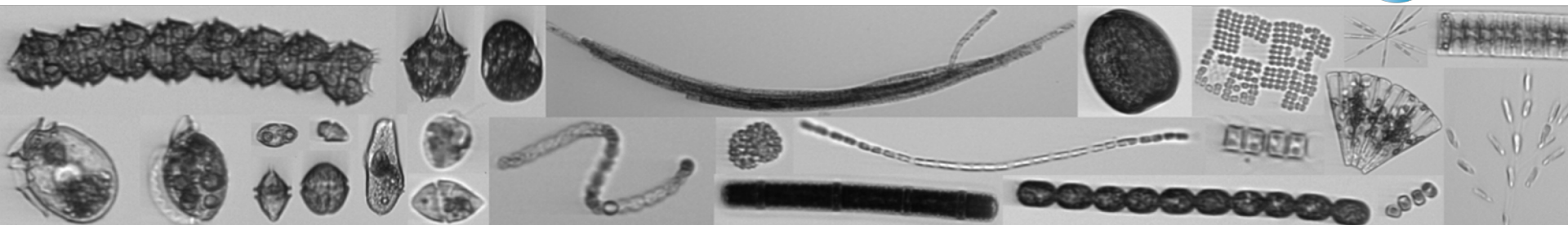
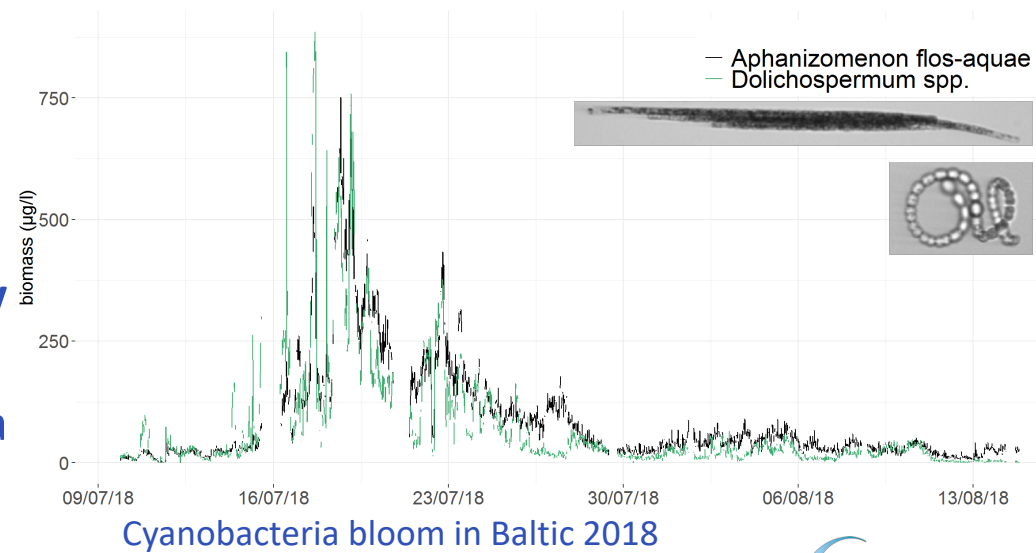
**N**

**CTD and geochemical data**

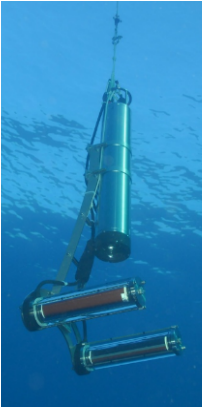


# Case study 1: long term monitoring – phytoplankton in the Baltic with IFCB

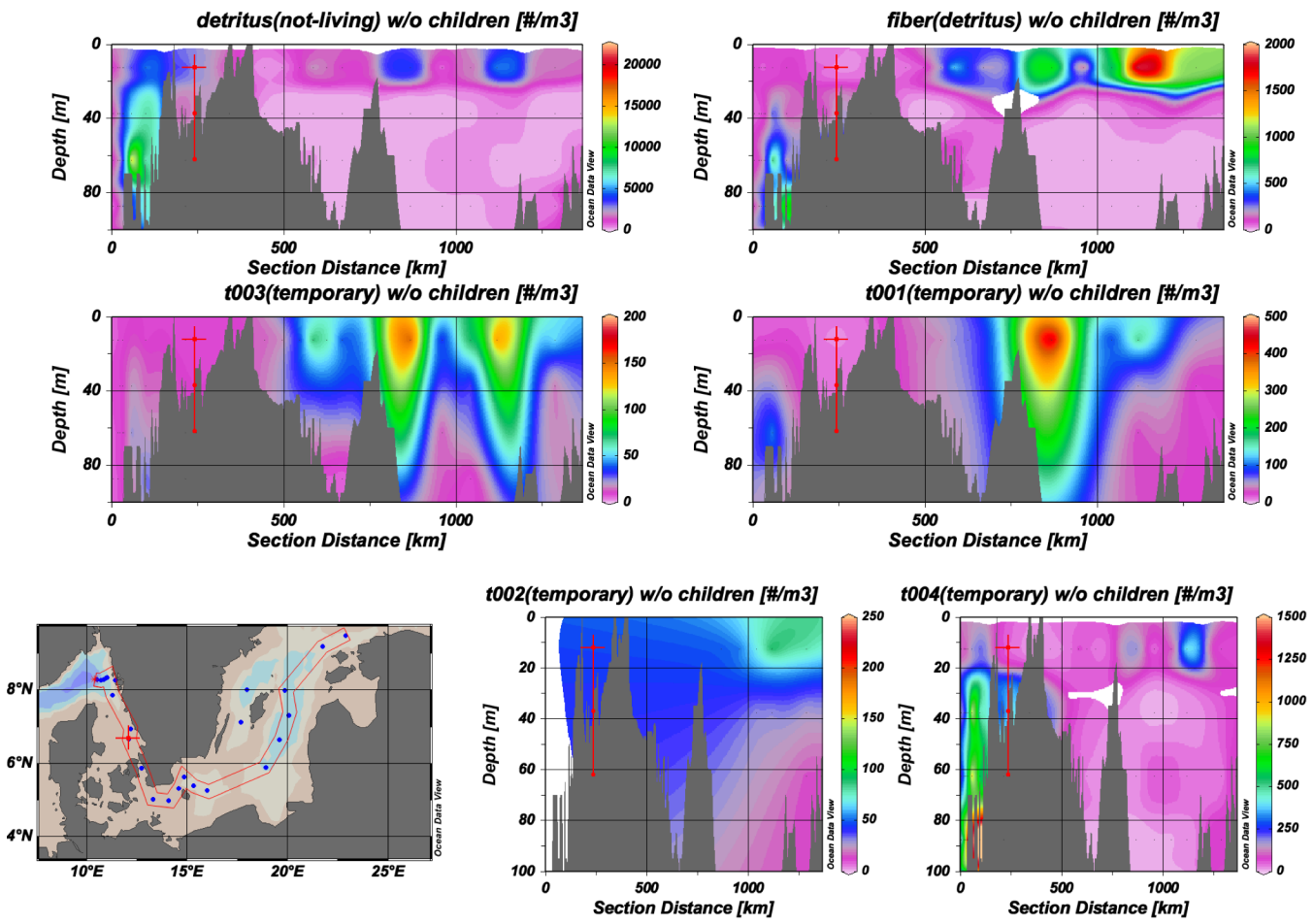
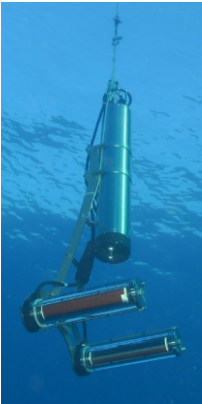
- ❖ IFCB has been deployed at Utö Atmospheric and Marine Research Station (Baltic Sea, Finland) in **2017 and 2018**
- ❖ So far **60 taxonomic categories** identified
- ❖ **creating classifier** for nuisance filamentous cyanobacteria,
- ❖ IFCB data used at SYKE for **weekly algal reviews in 2018, to inform public** on extensive cyanobacteria blooms



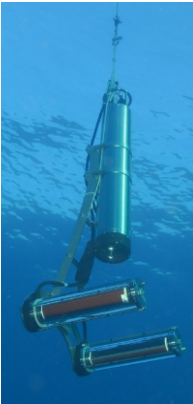
# Case study 2: Spatial monitoring of cyanobacterial blooms in the Baltic (July 2017) with UVP5



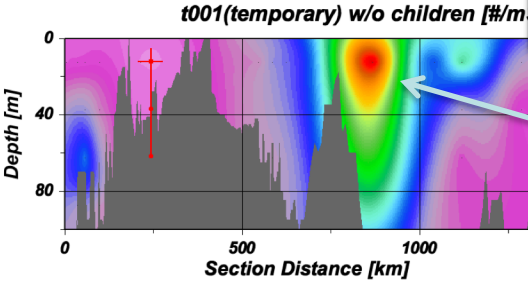
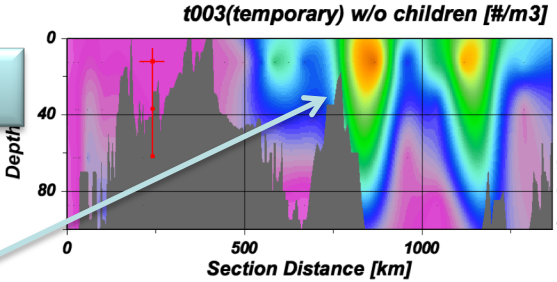
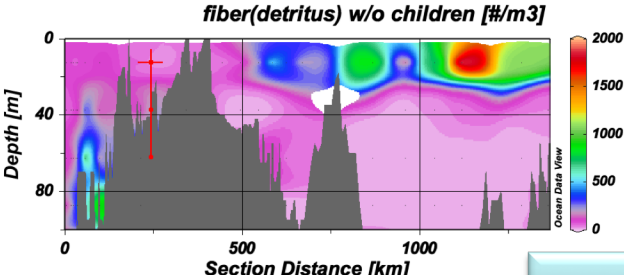
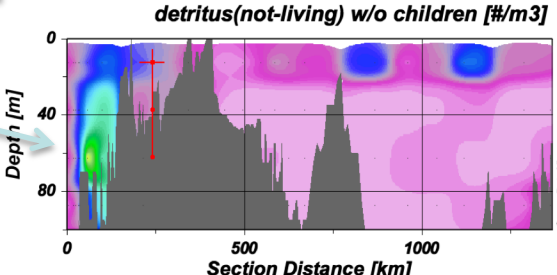
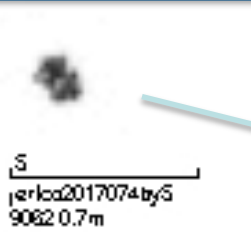
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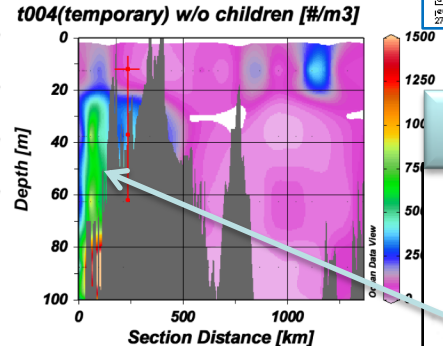
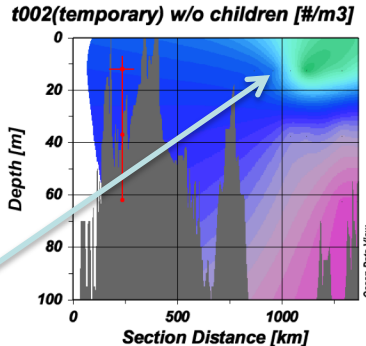
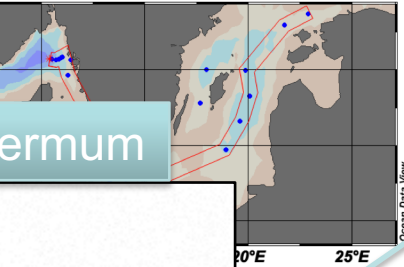
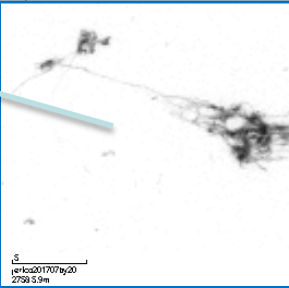
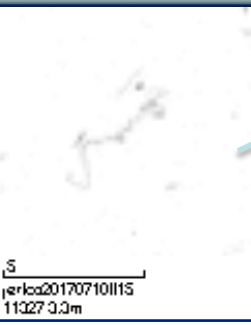


Aggregates

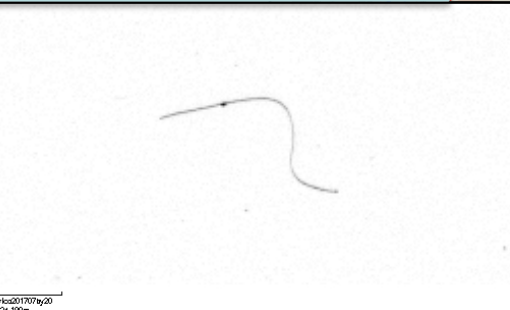


cf. *Aphanizomenon*

cf. *Nodularia*



cf. *Dolichospermum*



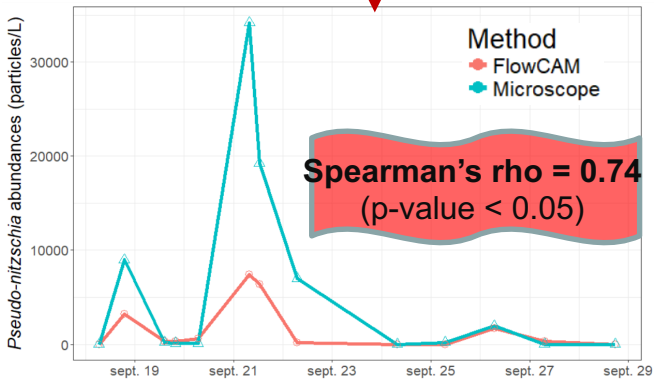
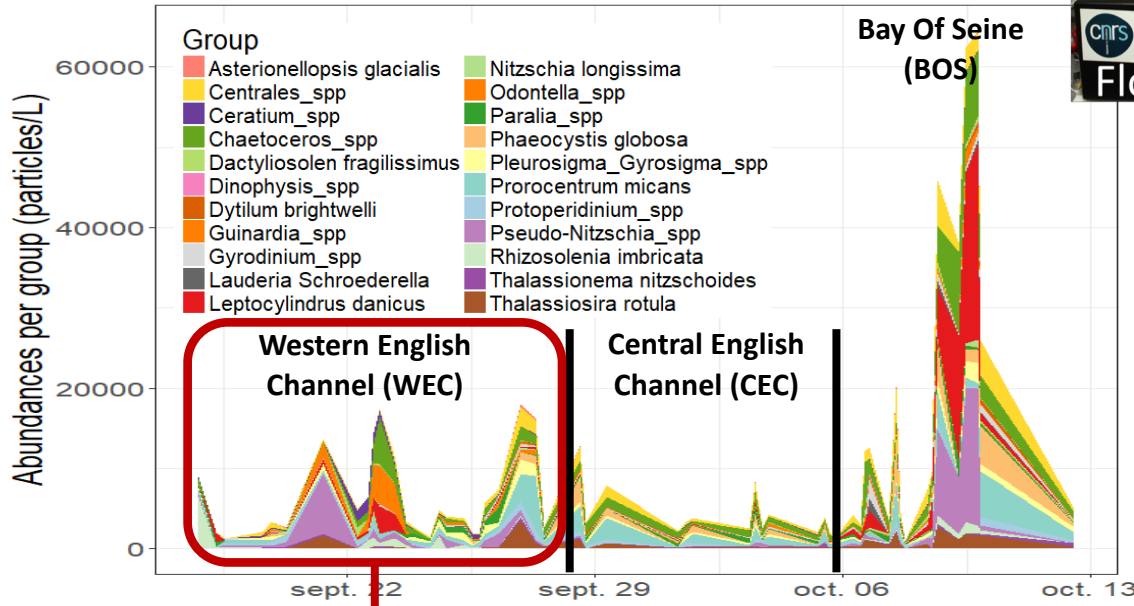
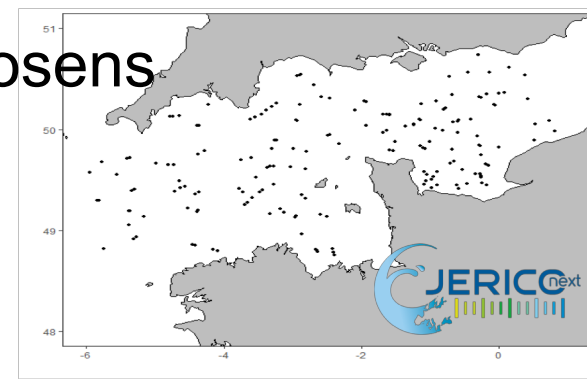
« Stringers »





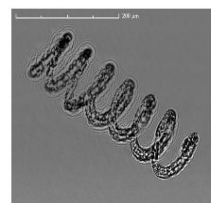
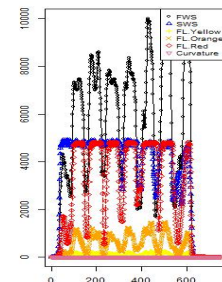
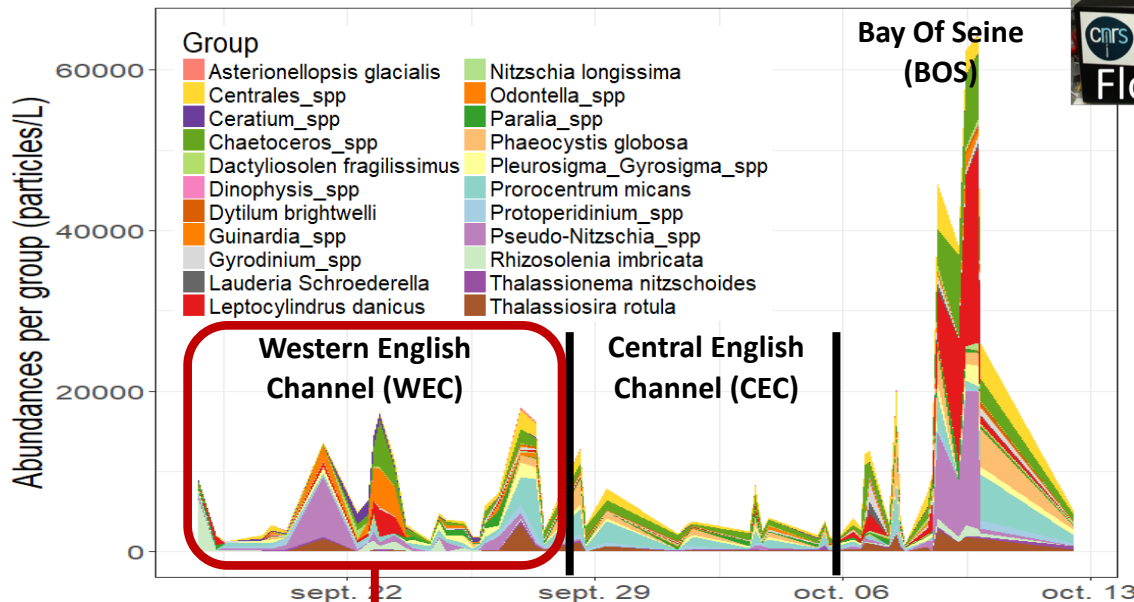
# Case study 3: Monitoring with FlowCam, Cytosens

**Period:** 16th September-12th October, 2014  
**Area:** Channel (R/V « Thalassa II » - IFREMER)  
**Classifier:** Random Forest

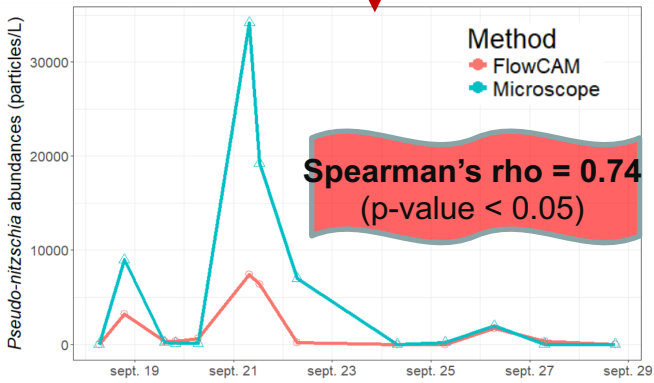
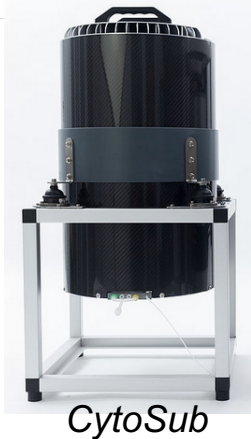


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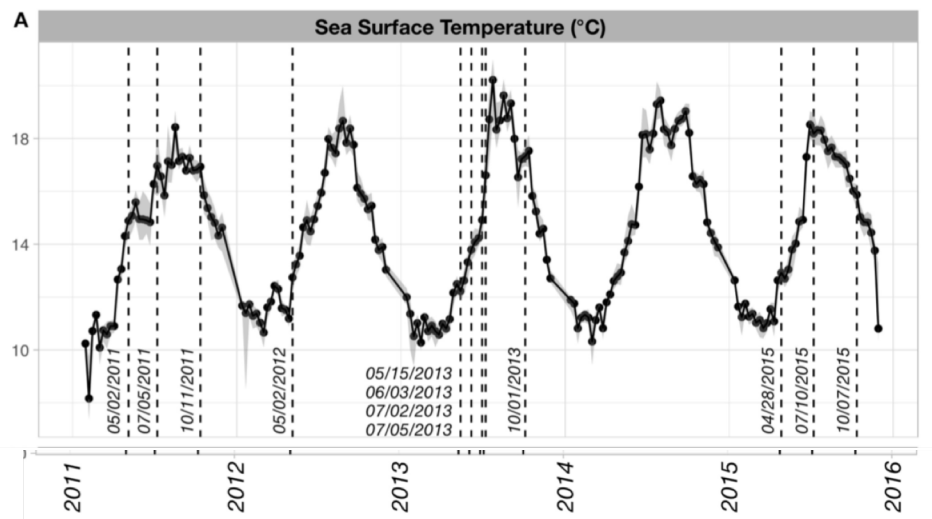
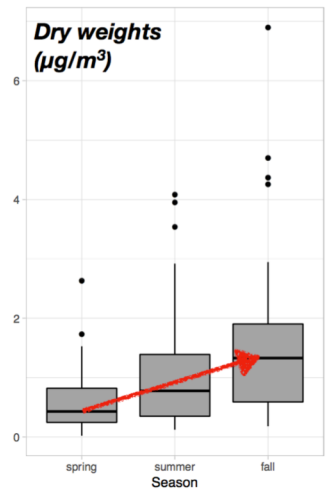
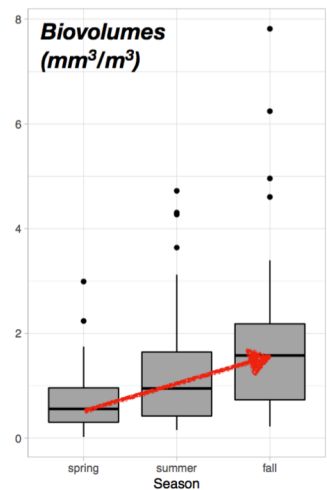
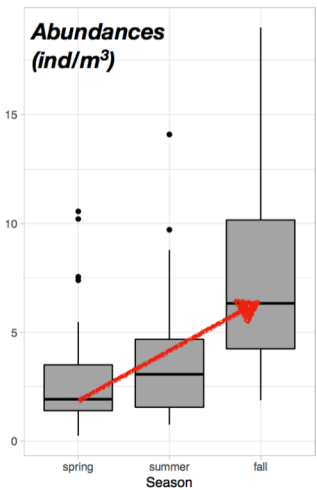
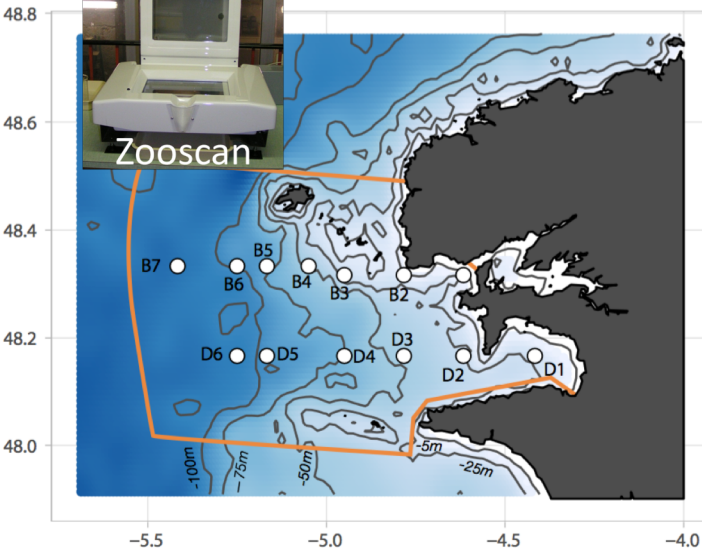


*Guinardia spp.*

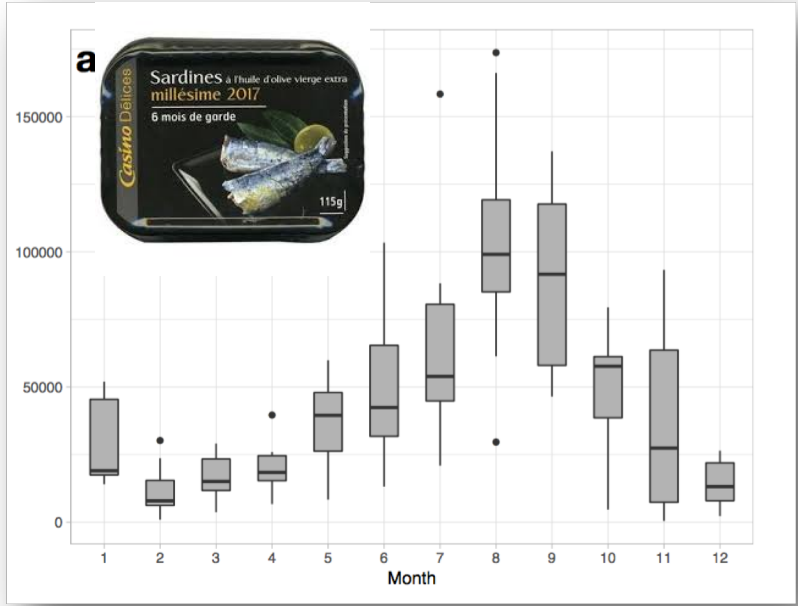
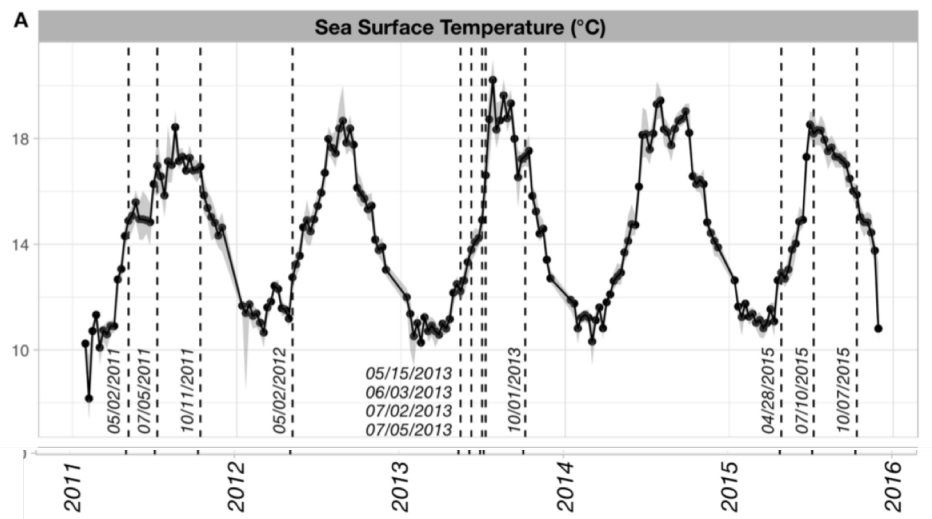
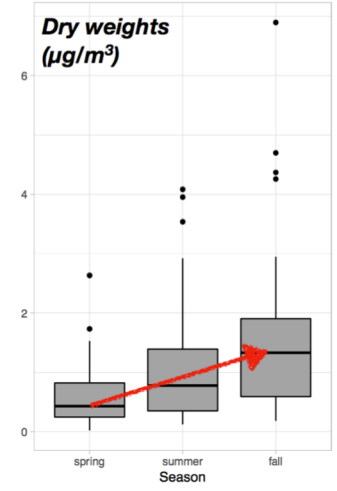
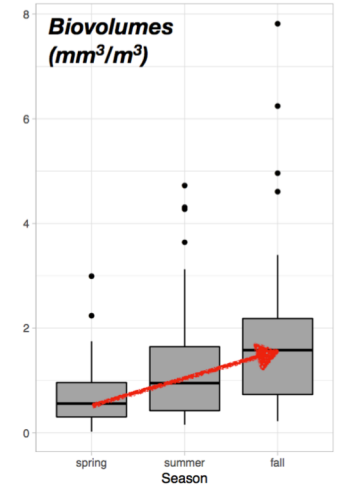
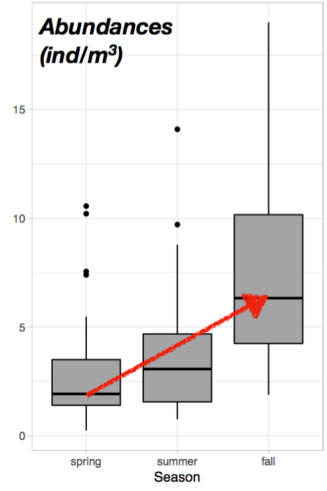
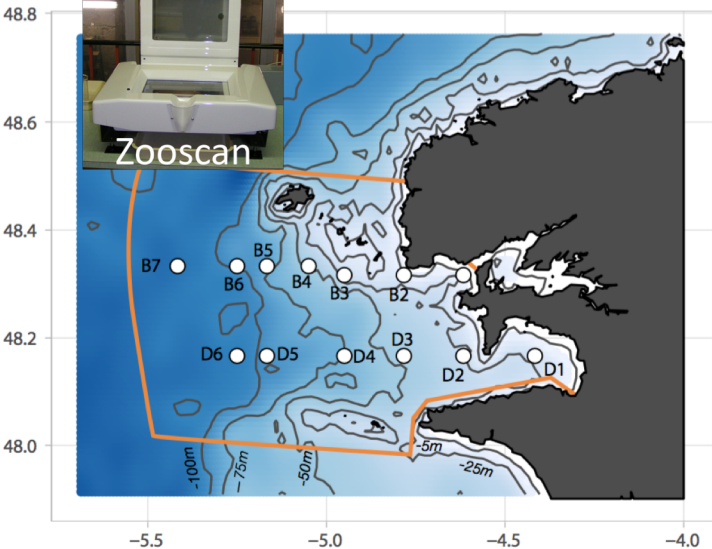


**Overall dynamics** of abundances obtained by microscopy and FlowCam for *Pseudo-Nitzschia* genus are **close**.  
**Building training set** coupling optics and images by Cytosens  
**Develop classifiers**

# Case study 4: Monitoring zooplankton in a MPA (2011-2015)

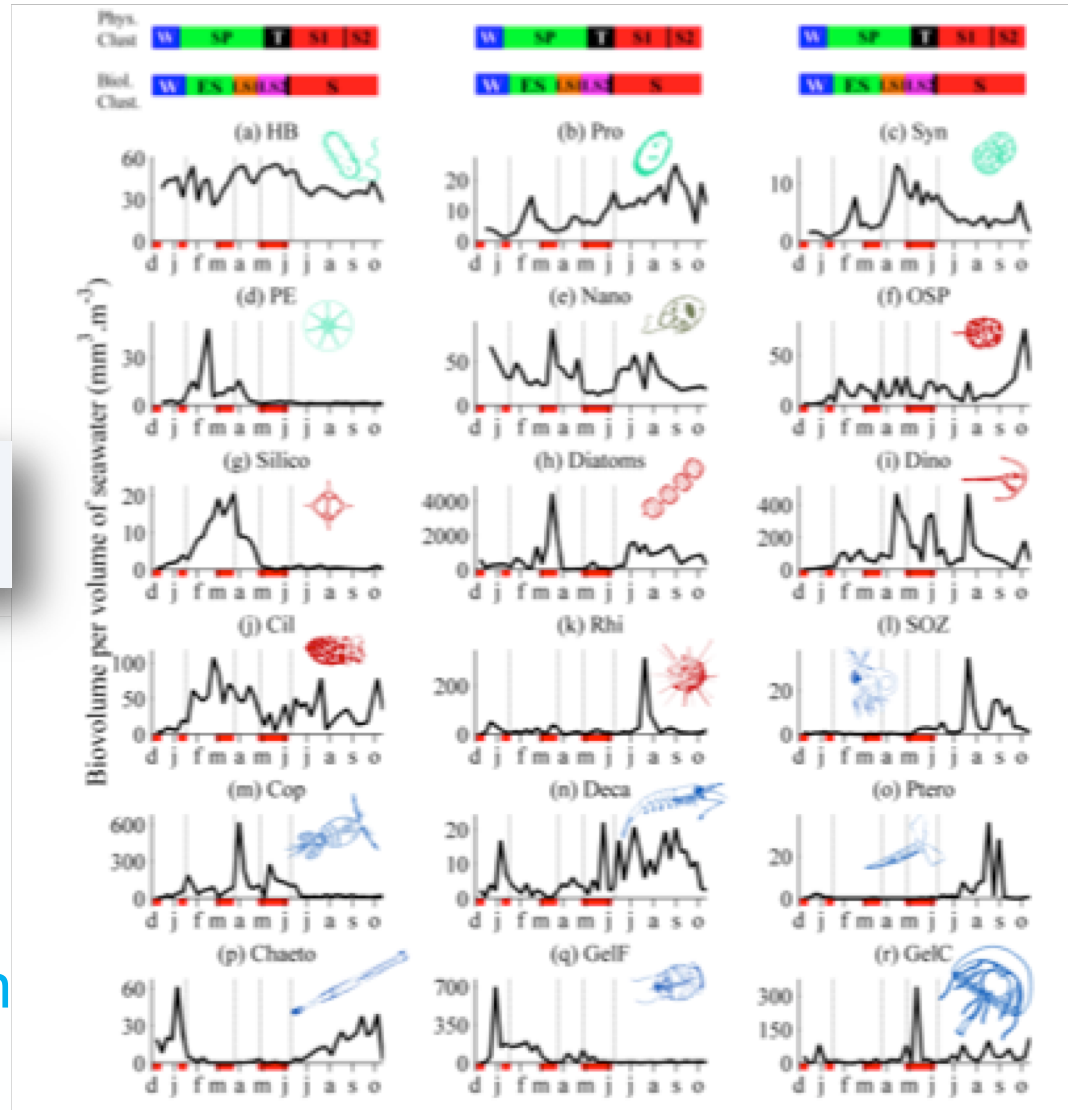
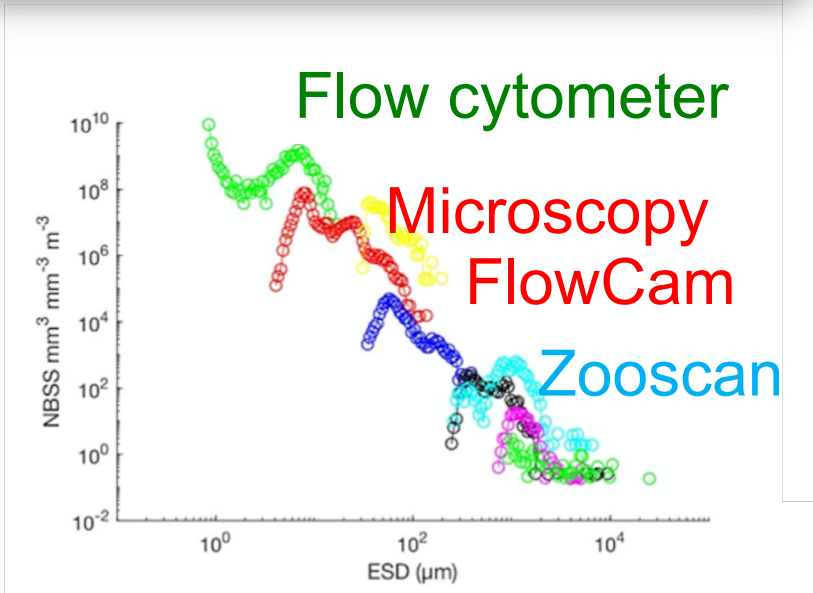
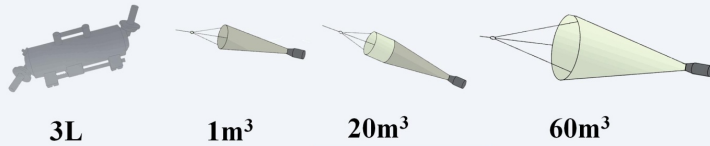
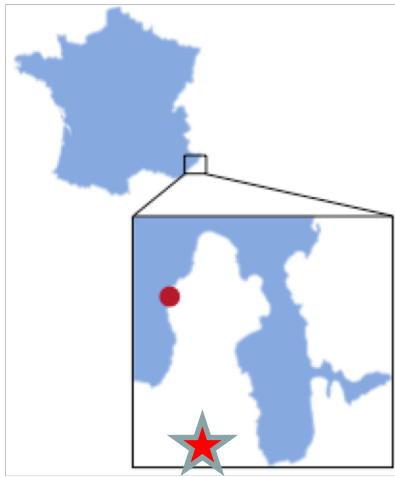


# Case study 4: Monitoring zooplankton in a MPA (2011-2015)





# Case 5: Time series of the whole pelagic ecosystem

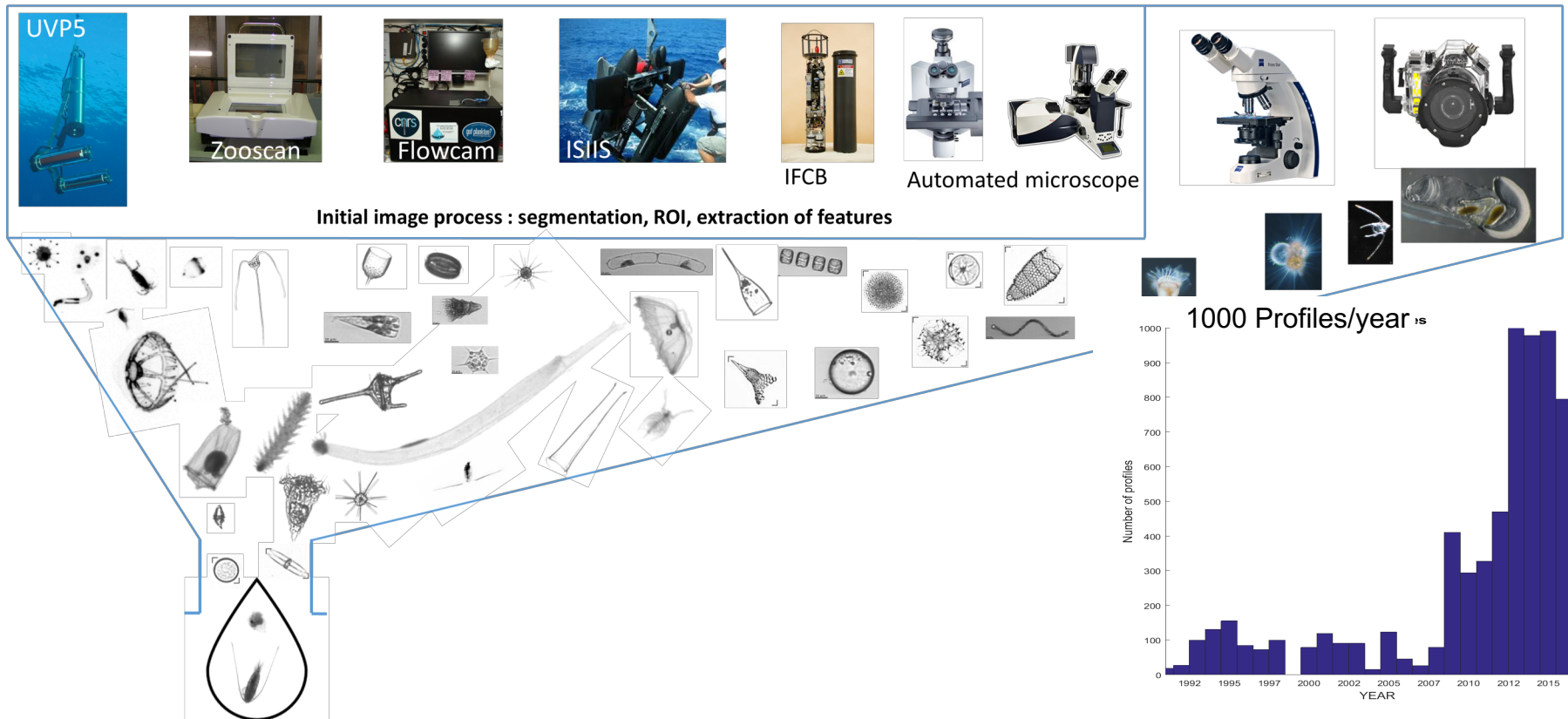


# Lessons learned from end-to-end approach

Imaging can bring a common and unified measurement across plankton types

Need for inter-calibration

Current technological breakthrough for extensive observation of plankton - eEOV, EBV



**Bottlenecks: manual classification and/or validation, lack of local expert**

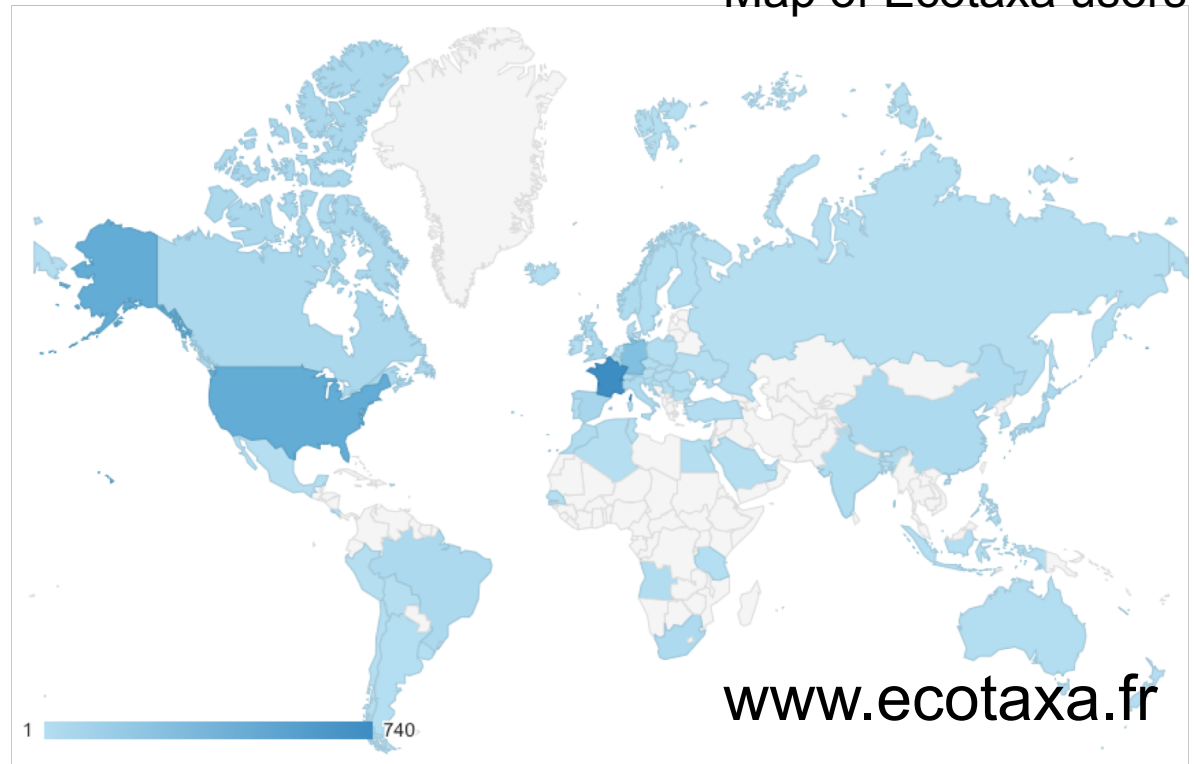
# Ecotaxa : a first step toward distributed plankton data

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

- Built-in automatic classification algorithms (random tree forest, CNN networks)
- 543 users/ 156 organisations (about 40 simultaneous users) → 80 10<sup>6</sup> images
- About 11 types of instruments (IFCB, Cytosense in test, flowcam, zooscan, zoocam, UVP, LOKI, eHFCM, bioscope, planktoscope... still growing)
- Full control of dataset and permissions by data-owner

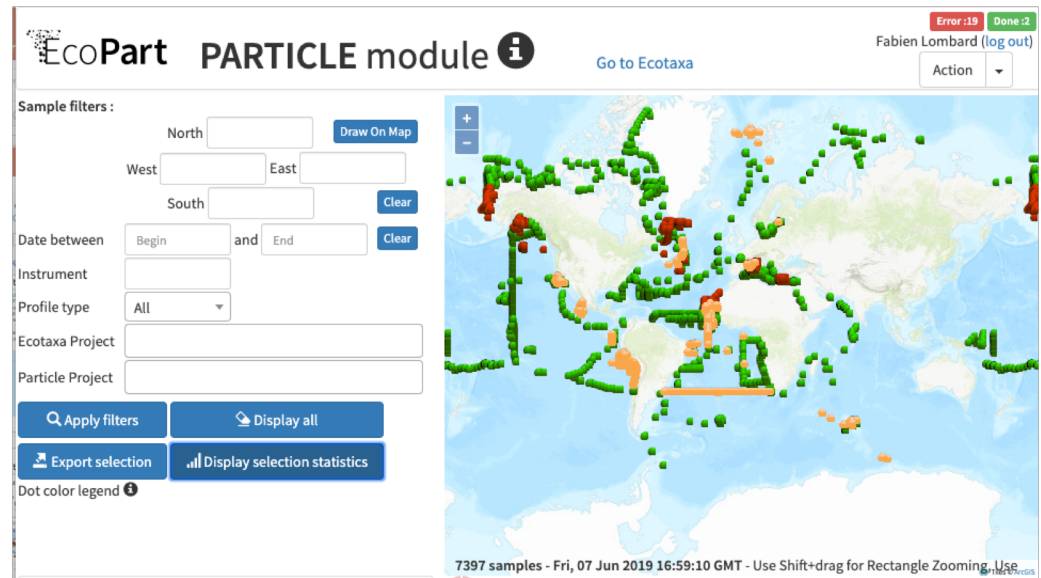
The screenshot shows the Ecotaxa 2.0 web interface. On the left is a search and filter panel with fields for Project, Sample, Depth (Min/Max in meters), Location (North/South/West/East), Date (Begin/End/Month), Time (invert, Begin/End, Day time), and Instrument. The main area displays a global map of all objects, with a zoom level of 10. Below the map is a grid of image thumbnails for various plankton species, including Calanus, Chaetognatha, Oncaea, Microcalanus, and Calanoida. The interface also shows a user profile for Fabien Lombard and a 'Randomly selected project: LOKI\_PS93.2/82'.

Map of Ecotaxa users



# Ecotaxa : a first step toward distributed plankton and particle data for real time monitoring

Plankton, particles and marine snow data



## Future: World Wide Web of Plankton Image Curation

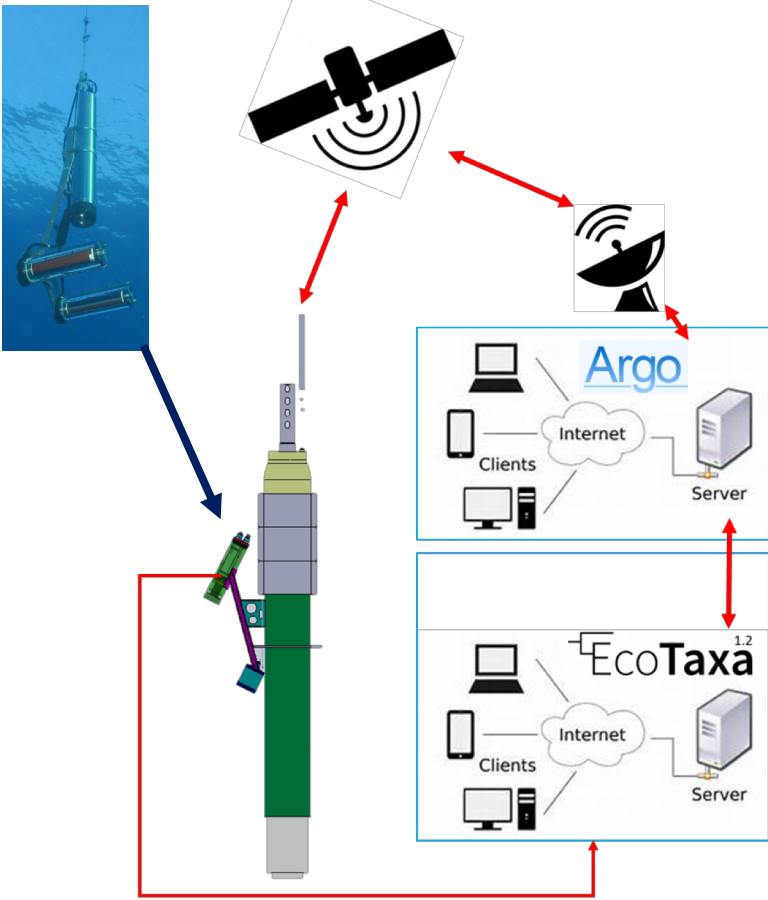
- 3 more servers (US, Brazil, Japan) under a joint infrastructure
- Scaling up from million to billion images
- linking with OBIS and other global repository
- better recognition algorithms
- better export and visualisation of results
- better import from different sensors





# Build a camera for float

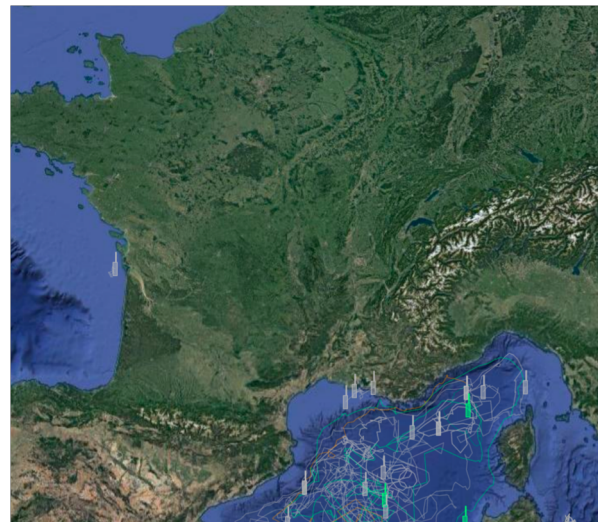
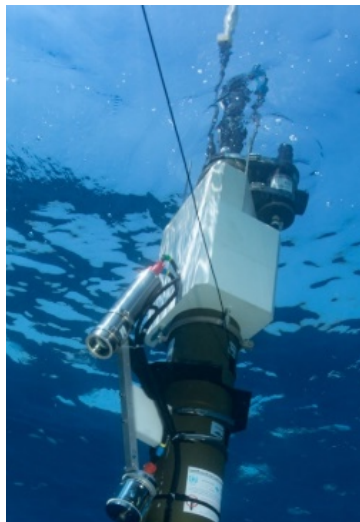
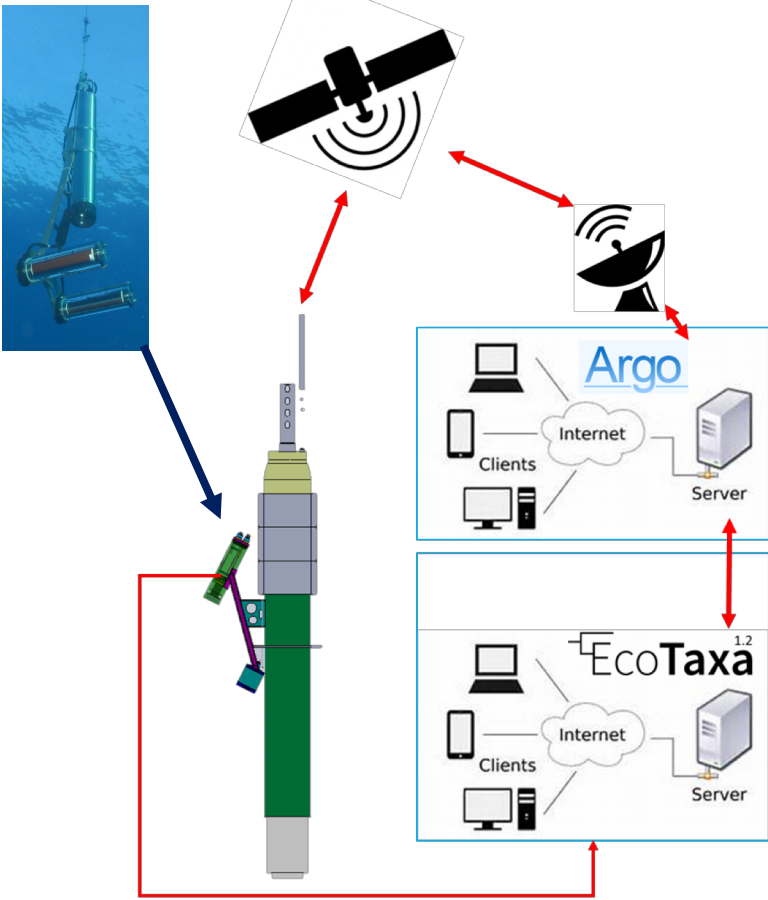
## ARGO France June 2012, BREST



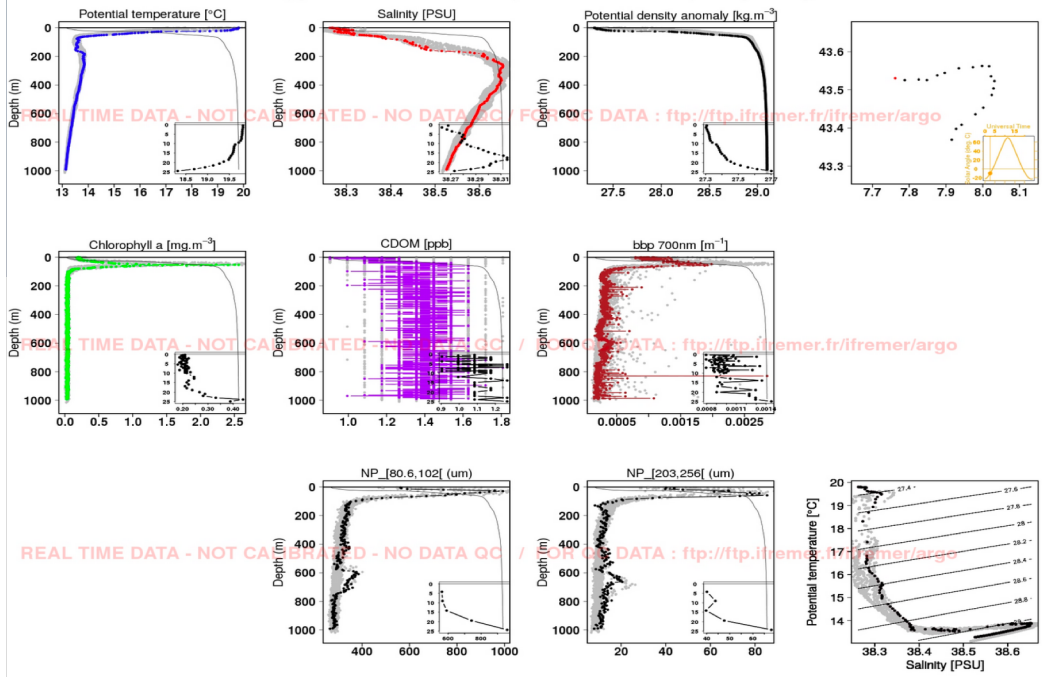
# Build a camera for float

## ARGO France June 2012, BREST

# 2019: time/space surveys by UVP6



Ascent / 16 Jun 2019 02:36 UT / lovapm015b\_4279\_056\_01\_09  
 Jpeg created on Sun Jun 16 15:45:29 2019 with data processed on Sun Jun 16 15:44:22 2019 (Lon:7.76deg, Lat:43.53deg)



## take home message

- **Images can be obtained with high throughput imaging systems for the whole plankton community**
- **Large image datasets can be analysed by a community of scientists and data can be easily shared for regional and global studies**
- **Images provide new information revealing poorly known fragile groups**
- **Plankton size distribution per taxa is more informative than only total plankton size distribution .**

# THE KEY OF THE SUCCESS:

## → TECHNOLOGY

- → RELIABLE IMAGING SENSORS (lab, in situ, autonomous)
- → IMPROVING RECOGNITION
- → « friendly » SOFTWARE for image analysis, data streaming

## ○→ COORDINATION

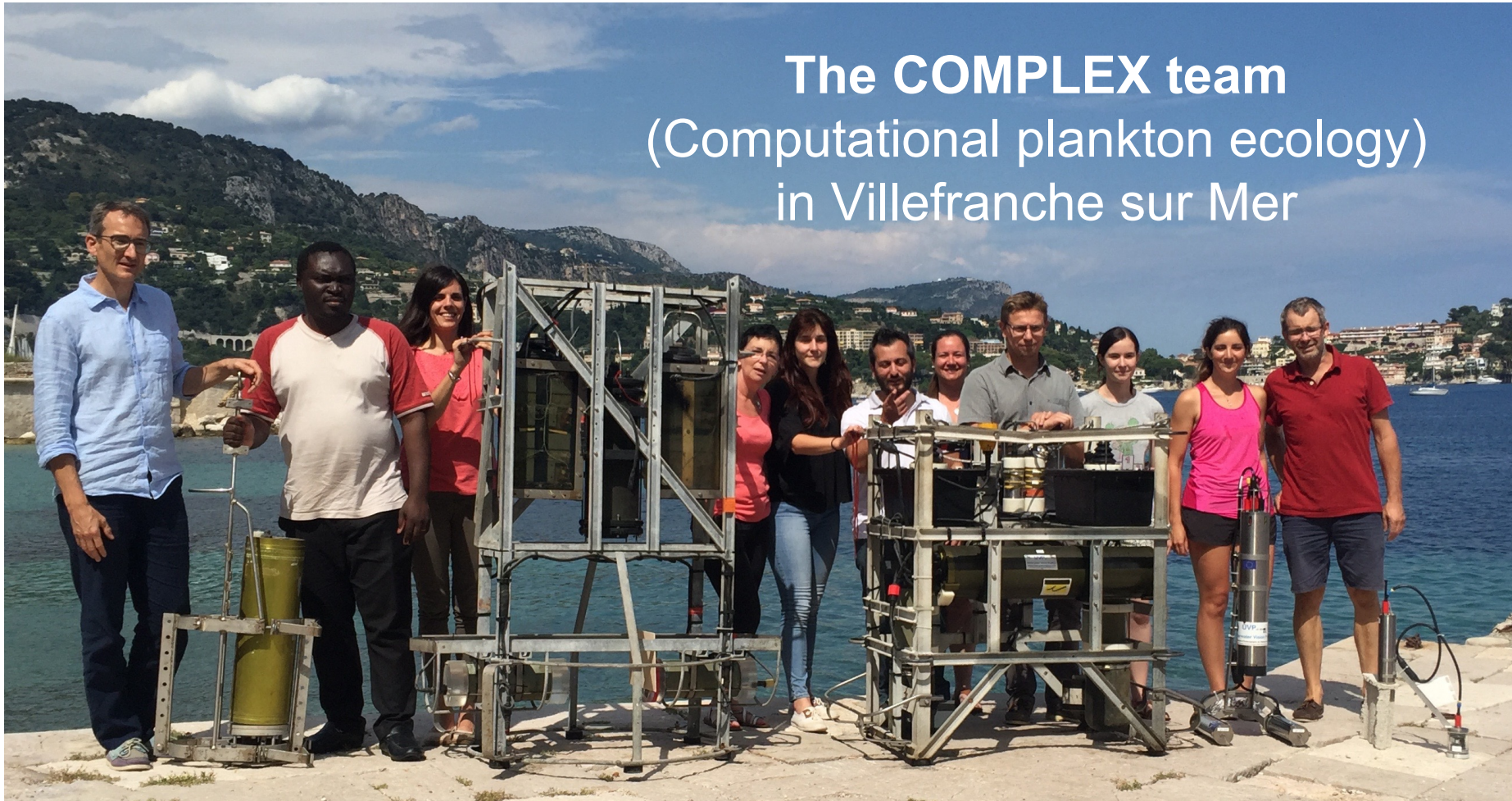
- AGREED USE: It is not a question of more data but the « right » data at « right » location for the good scientific reason
- AGREED PROCEDURES (image format, treatment, semi-automatic recognition, intercalibration)
- AGREED DATA MANAGEMENT AND DISTRIBUTION
- COMPATIBLE TO MODELING FRAMEWORKS

*Be fast, be collaborative, be opportunistic (Alistair Hobday, Imber Brest 2018)*



Thank you for your attention,  
Any questions?

The **COMPLEX** team  
(Computational plankton ecology)  
in Villefranche sur Mer



UVP1  
1991

UVP2  
1992-1996

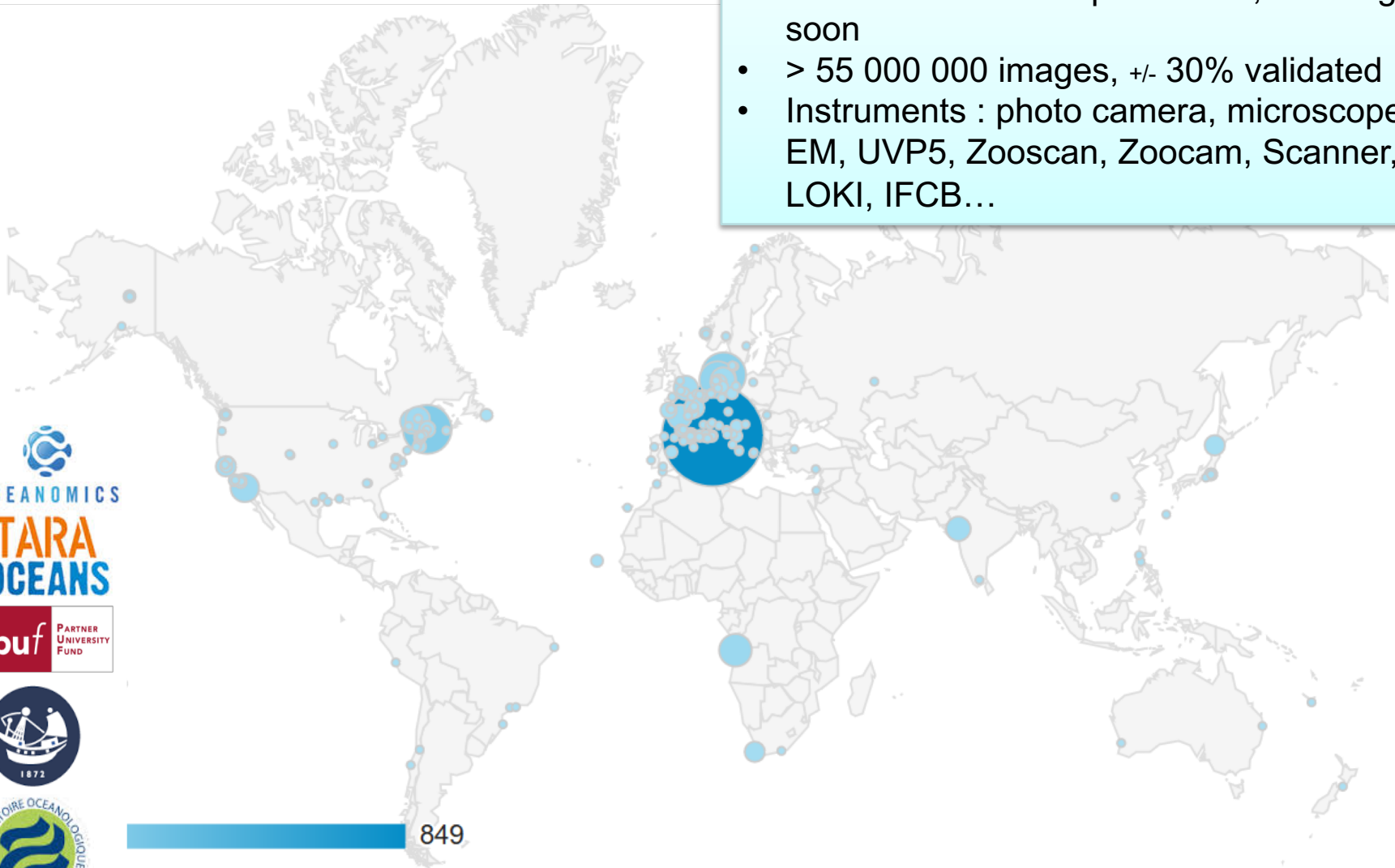
UVP3-4  
1996-2008

UVP5  
2008-..

UVP6  
2018-..

# EcoTaxa today


- 2 main instances implemented, one to go soon
- > 55 000 000 images, +/- 30% validated
- Instruments : photo camera, microscope, EM, UVP5, Zooscan, Zoocam, Scanner, LOKI, IFCB...





# Case study 2: Spatial survey of cyanobacterial blooms in the Baltic

EcoTaxa<sup>1.3</sup>

PARTICLE module 

Not logged (log in)

Sample filters:

North    
West  East   
East   
South


Date between  and

Instrument

Profile type

Ecotaxa Project

Particle Project

Dot color legend 

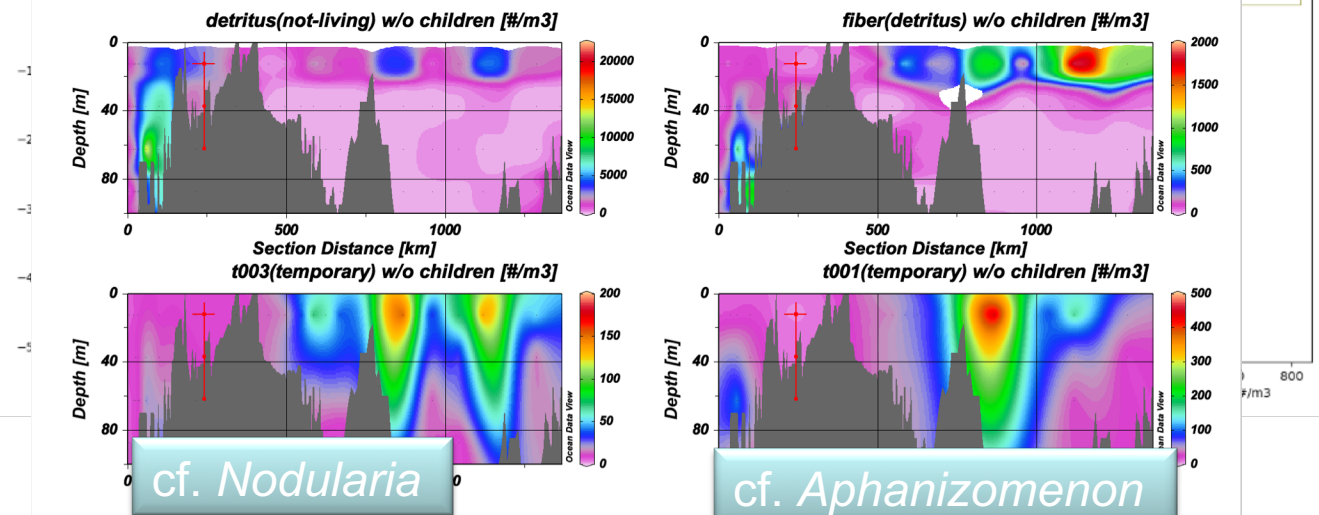
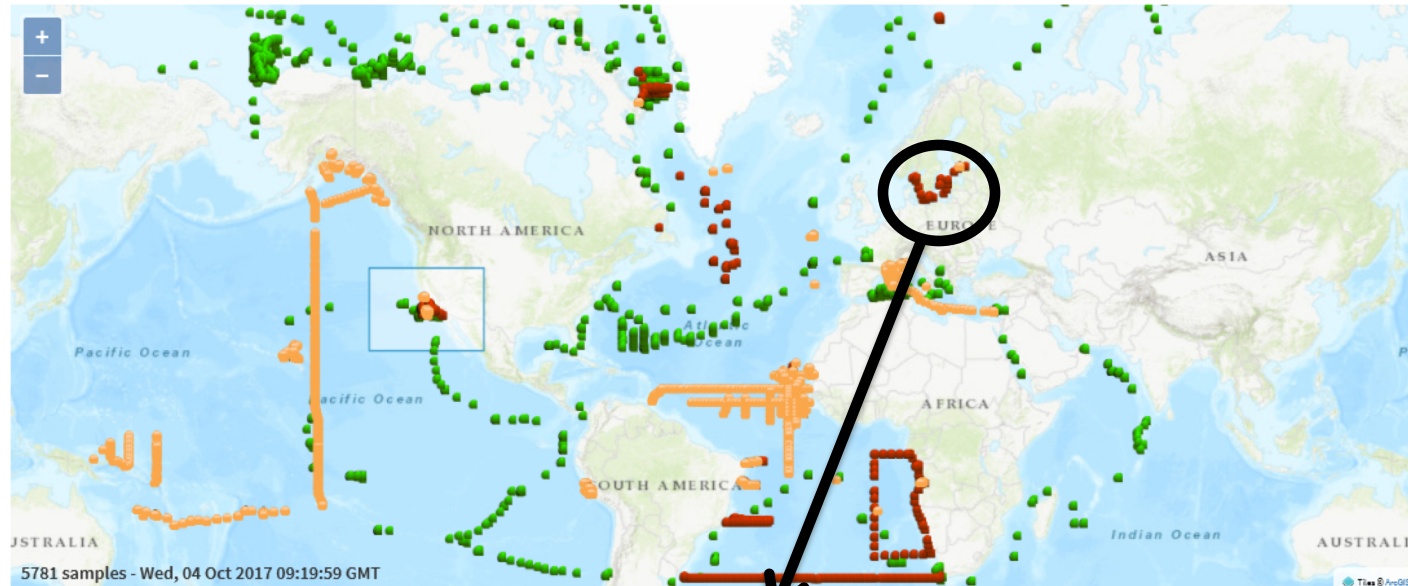
Graph configuration

Reduced particle histogram -

Detailed particle histogram -

Log  Symlog

children categories



# Case study 3: Spatial surveys around the world


EcoTaxa<sup>1.3</sup>

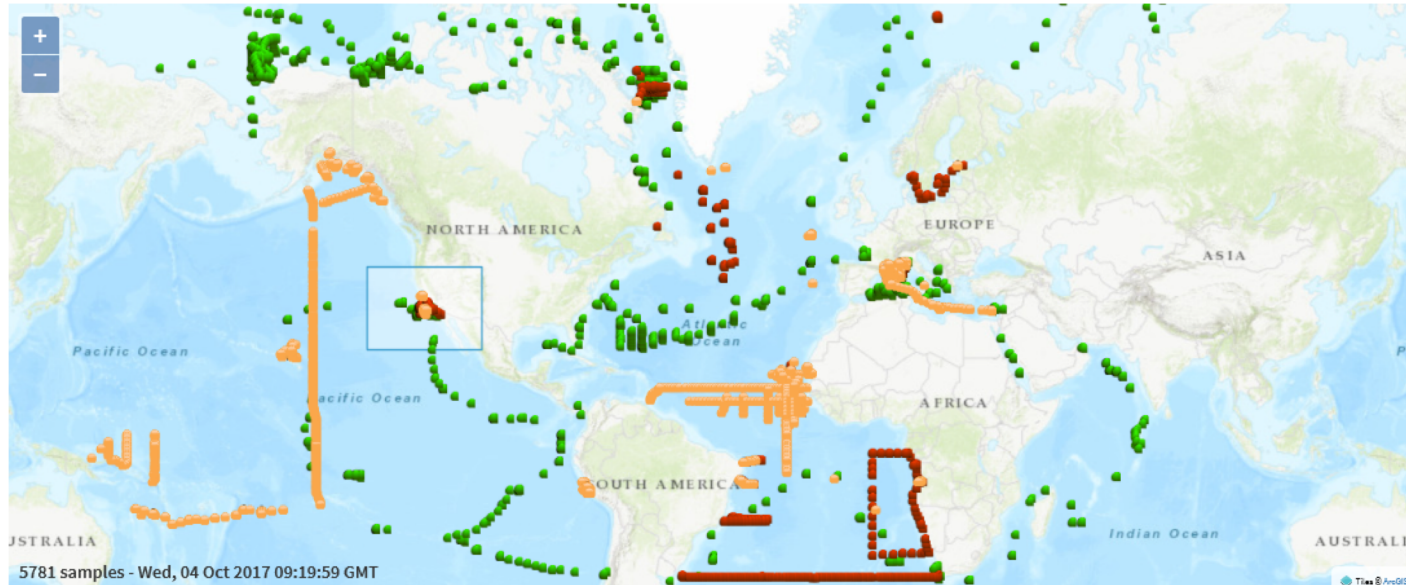
PARTICLE module 

Not logged (log in)

Sample filters:

North    
West  East   
East   
South    
Date between  and    
Instrument   
Profile type   
Ecotaxa Project   
Particle Project

Dot color legend 

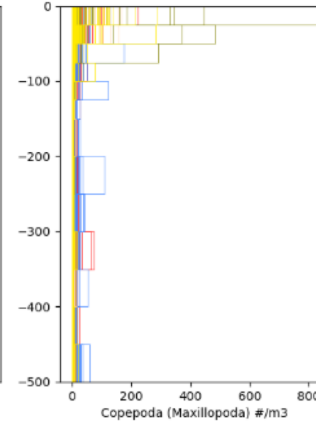
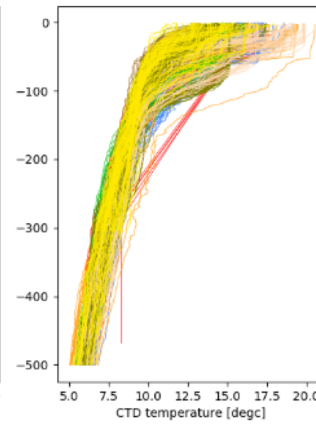
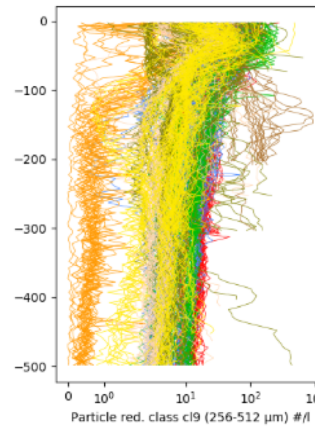
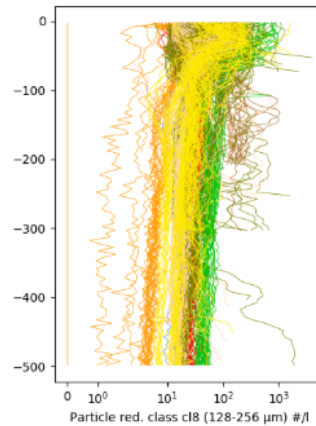


Graph configuration

Reduced particle histogram -

Detailed particle histogram -

Log -  Symlog





# Ecotaxa : a first step toward distributed data

Free exploration of validated images

Launched in 2016 ... 80 million images now (42% validated)

Powerful filters

Powerful manual annotation (>20 000 day<sup>-1</sup>)

Explicit taxonomy (UniEuk→WORMS)

Ecotaxa 2.0 Exploration  
Randomly selected project : LOKI\_PS93.2/82  
Fabien Lombard (log out)

Update view & apply filters  
img/page : 50 Zoom : 10

Clear filters Share page  
Hide filters

Project  
Sample  
Depth  
Location  
Date  
Time  
Instrument  
Validated Plankton filter

Global map of all objects of the application. (To see filtered for a project or a taxon use 'Open map')

Calanus Chaetognatha Calanus Oncaea  
artifact Microcalanus Oncaea Calanoidea

Ecotaxa 2.0 Photo bino Fabien Lombard (232, 0, 0, 7 / 239)  
Fabien Lombard (log out)

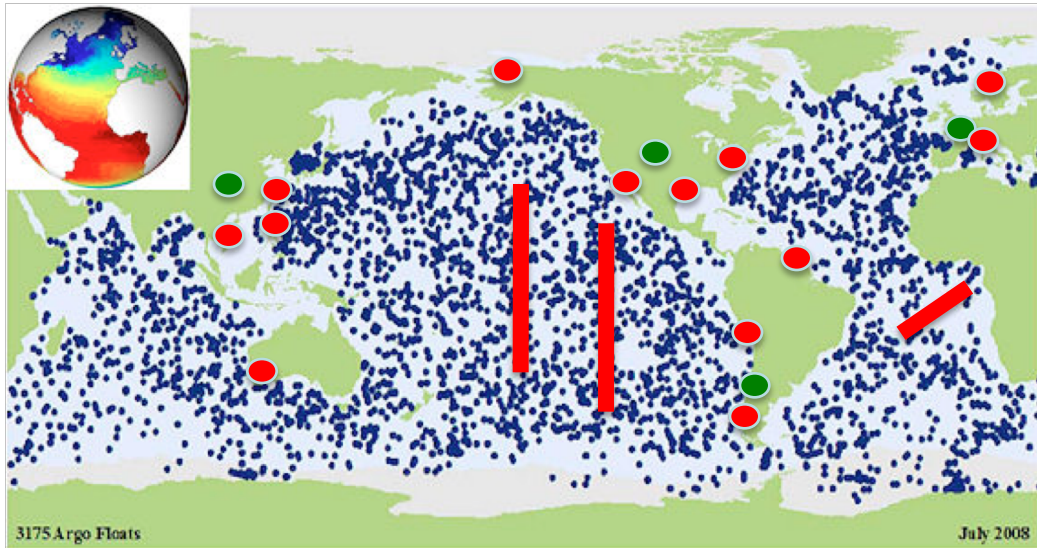
Update view & apply filter  
Select all Display Status All 100% 10

Taxonomy filter Other filters

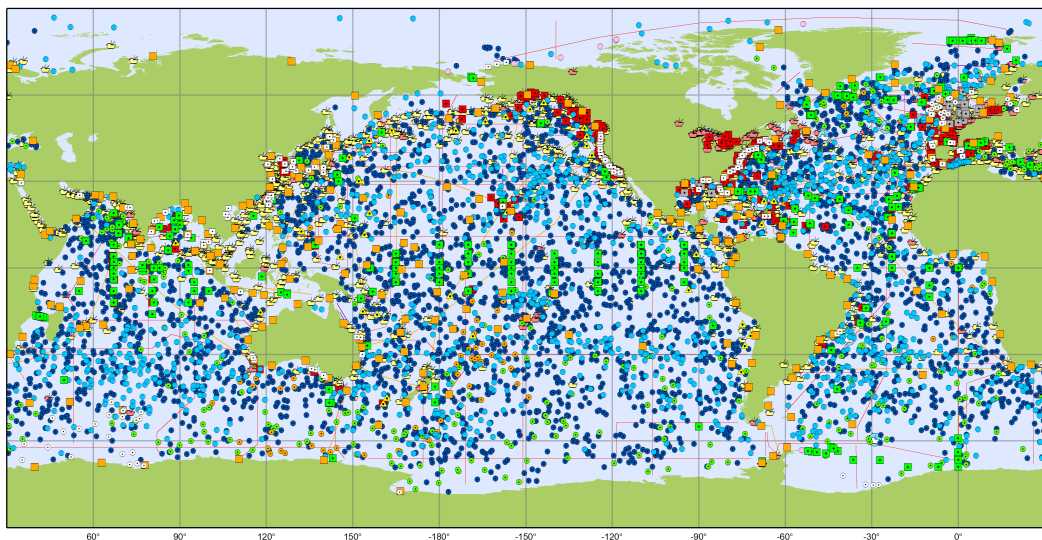
living  
Abyliidae  
Acantharea  
Amphipoda  
Phronima sp.  
Annelida  
Appendicularia  
Fritillaria pellucida  
Megalocercus abyssorum  
Oikopleura  
Oikopleura dioica  
Asterolamprales temp  
Bacteriastrium - Mediophyceae  
Chaetoceros - Mediophyceae  
Ciliophora  
Cyttarocylis cassis  
Eutintinnus apertus  
Corycaeus  
Coscinodiscus  
Decapoda  
megalopa  
Dictyota  
Dinophysis  
Ditylum  
Doliolum  
Echinodermata  
Euphausiacea  
Foraminifera  
Mollusca  
Cephalopoda  
Thecosomata  
Neoceratium  
Neoceratium furca

living living living living living  
living living Ciliophora Ciliophora Ciliophora  
Ciliophora Ciliophora Ciliophora Ciliophora Ciliophora  
Ciliophora Ciliophora Ciliophora Ciliophora Ciliophora  
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Ciliophora Ciliophora Ciliophora Ciliophora Ciliophora

# The 10 years vision, Plankton: global and regional monitoring with imaging systems



- Global network of observations**
- - ARGO-> BIOARGO +vision
  - - fixed stations + vision
  - ▬ - cruises of opportunity (vision on in line systems)
  - Oceanographic data center for QC and large diffusion

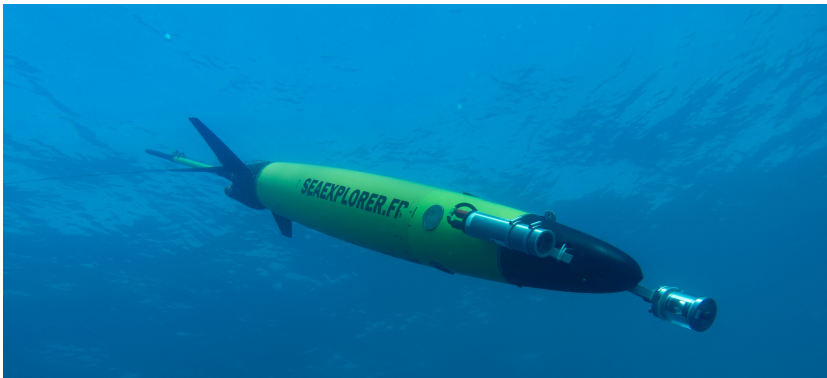
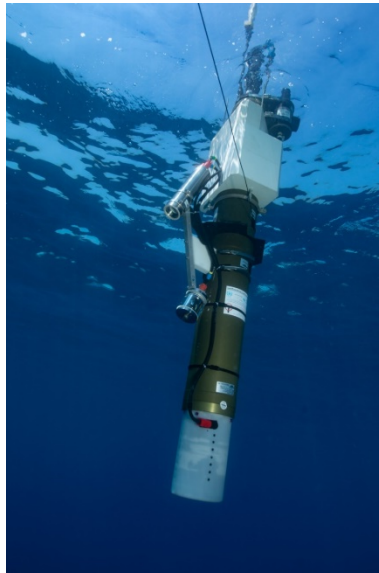
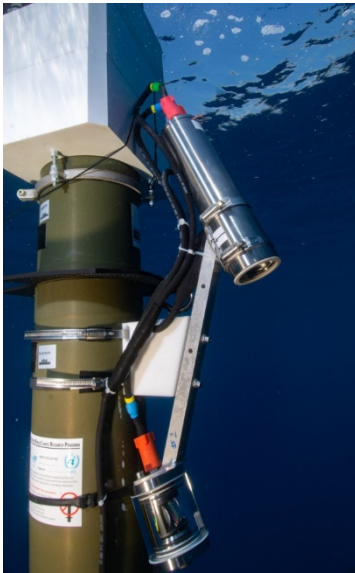


- |                                |                           |                                       |                                      |                             |
|--------------------------------|---------------------------|---------------------------------------|--------------------------------------|-----------------------------|
| <b>Profiling Floats (Argo)</b> | <b>Data Buoys (DBCP)</b>  | <b>Timeseries (OceanSITES)</b>        | <b>Ship based Measurements (SOT)</b> | <b>Other Networks</b>       |
| ● Core (3880)                  | ● Surface Drifters (1444) | ■ Interdisciplinary Moorings (351)    | ● Automated Weather Stations (257)   | ○ HF Radars (270)           |
| ● Deep (79)                    | ■ Offshore Platforms (97) | <b>Repeated Hydrography (GO-SHIP)</b> | ● Manned Weather Stations (1324)     | ○ Animal Borne Sensors (53) |
| ● BioGeoChemical (352)         | ● Ice Buoys (11)          | ● Research Vessel Lines (62)          | ● Radiosondes (11)                   | ○ Ocean Gliders (31)        |
|                                | ● Moored Buoys (358)      | <b>Sea Level (GLOSS)</b>              | ● expendable BathyThermographs (34)  |                             |
|                                | ▲ Tsunameters (38)        | ■ Tide Gauges (252)                   |                                      |                             |
- Generated by www.pommaps.org 14/05/2019



# UVP-6

Currently under tests and cross calibrations



Already planned in several large scale projects (H2020, ERC, ANR, ANR jcjc) Integration test on several vectors (gliders, Argo floats, moorings, ROV)

# Case study 2: Spatial survey of cyanobacterial blooms in the Baltic (July 2018) with UVP5

