UVP6 : a new low power, low cost and deep ocean rated imaging sensor for automatic quantification of particles and plankton from autonomous platforms

IS31A - Advancing Technologies for the Future of Deep-Ocean Exploration

Picheral et al.

The **Underwater Vision Profilers** are **in-situ camera** :

- **They count and size large particles** > 0.1 mm ESD
- **They permit to Identify plankton and aggregates** > 0.5 - 1 mm ESD

The instruments are utilized for :

- **Particle monitoring, biogeochemical studies (including carbon pump)**
- **Plankton ecology**

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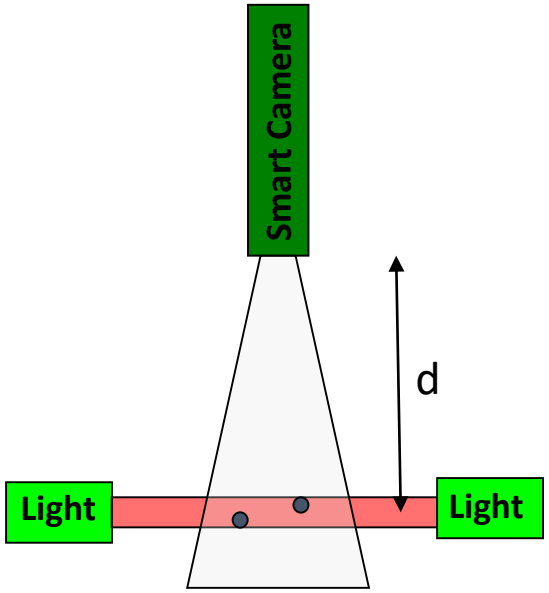
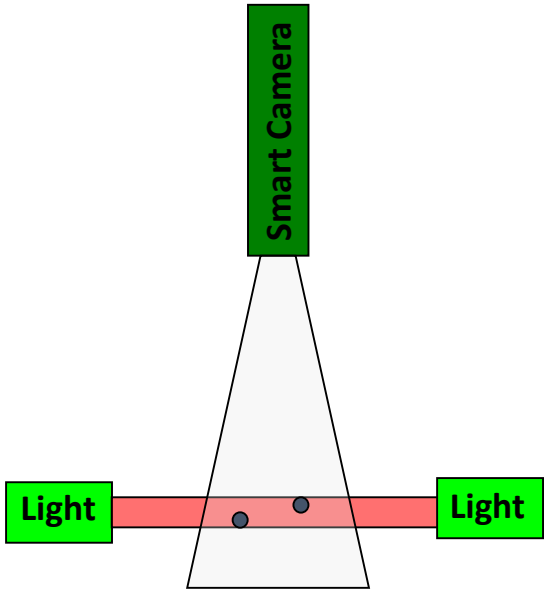


- Constant distance between camera and objects
  > **size measurements**
- Volumetric image
  > **concentration**

Versions 1 to 4 (single prototypes) :

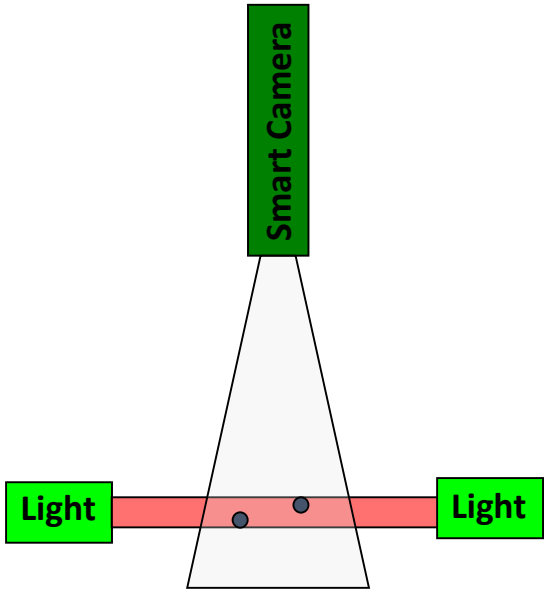


Versions 1 to 4 (single prototypes) :

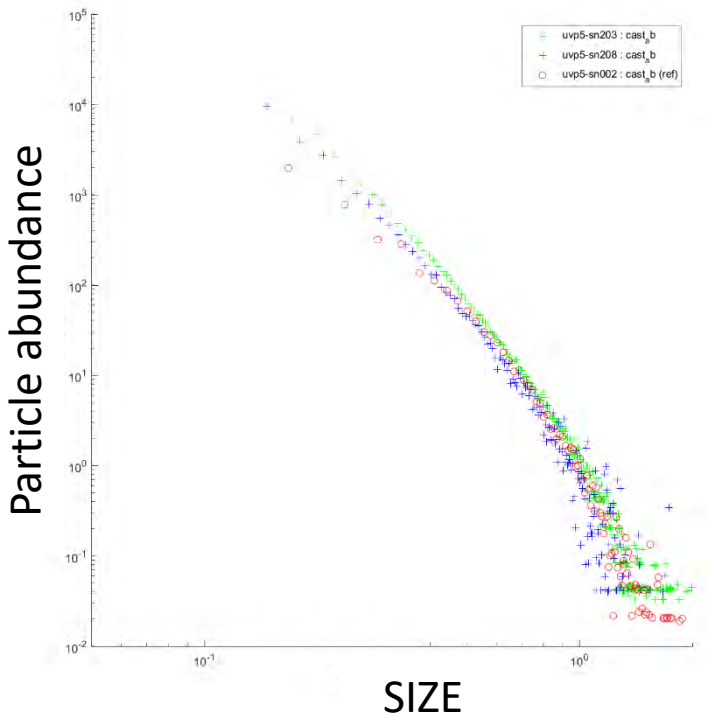
Version 5 std/hd (30 units worldwide)

- 6000m rated /35 kg
- 10-20 watts
- Sensor on CTDs

HYDROPTIC



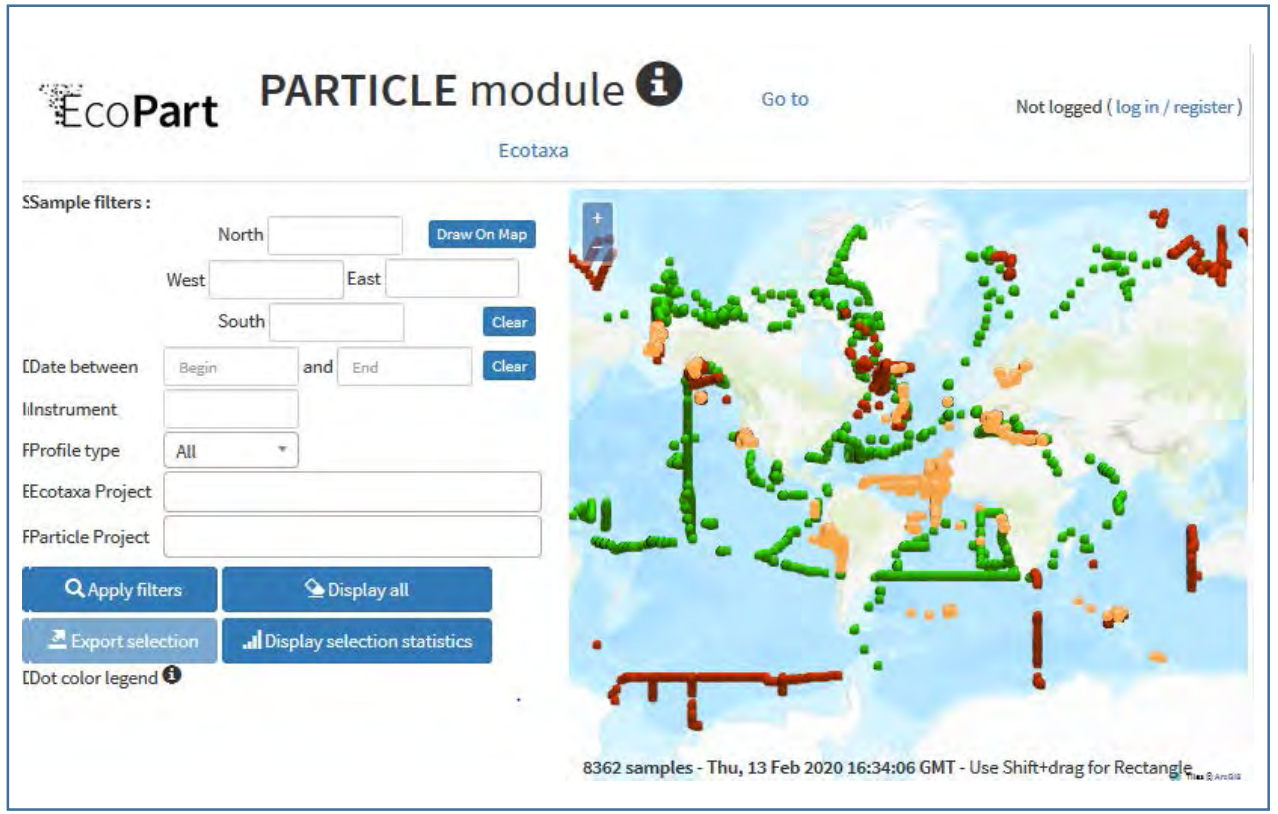
Picheral et al., LOM, 2010



The UVP5s are intercalibrated sensors

The UVP instruments benefit from a full **software ecosystem** : Zooprocess, UVPapp, Ecotaxa and EcoPart.

- **103** cruises from many institutions/countries
- **8360 profiles** loaded in 10 years
- **34 500 000** vignettes, **44.5**% classified and visually checked



https://ecotaxa.obs-vlfr.fr/

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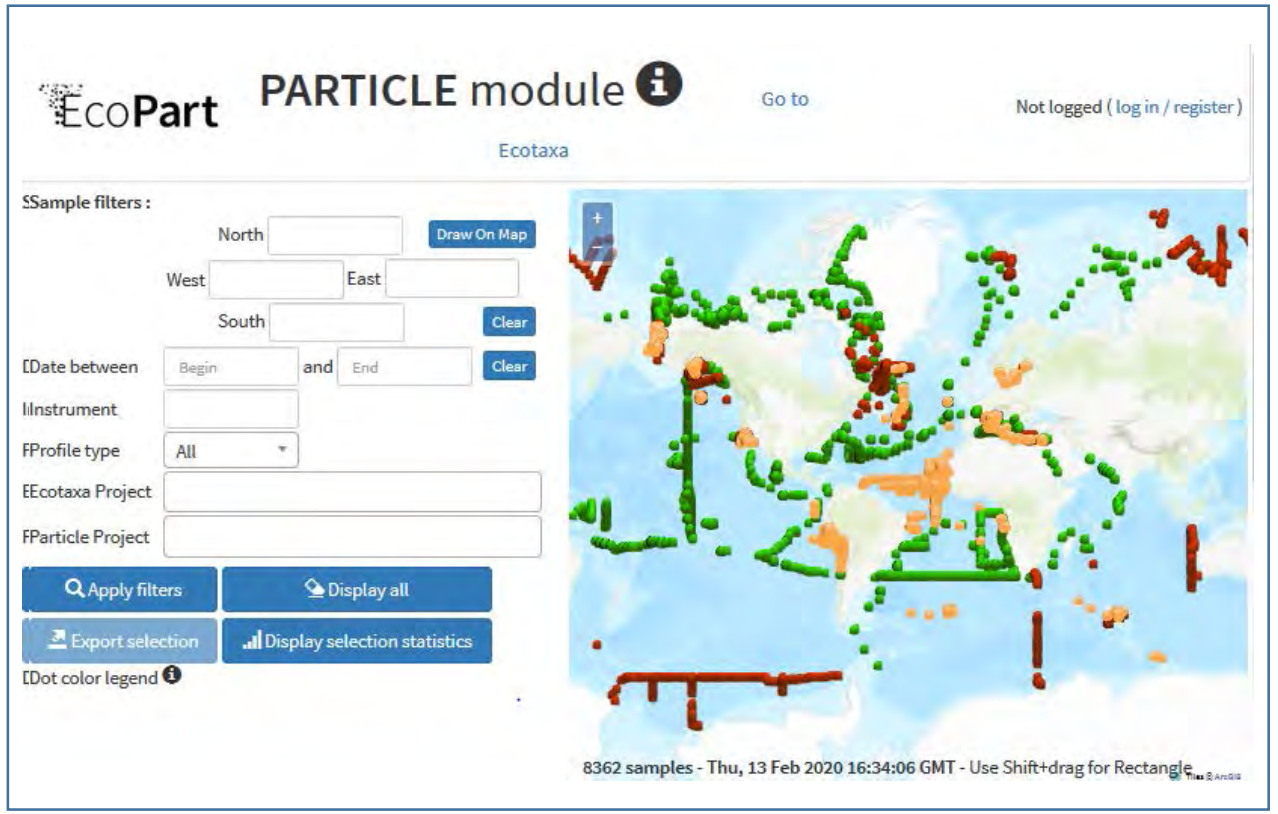

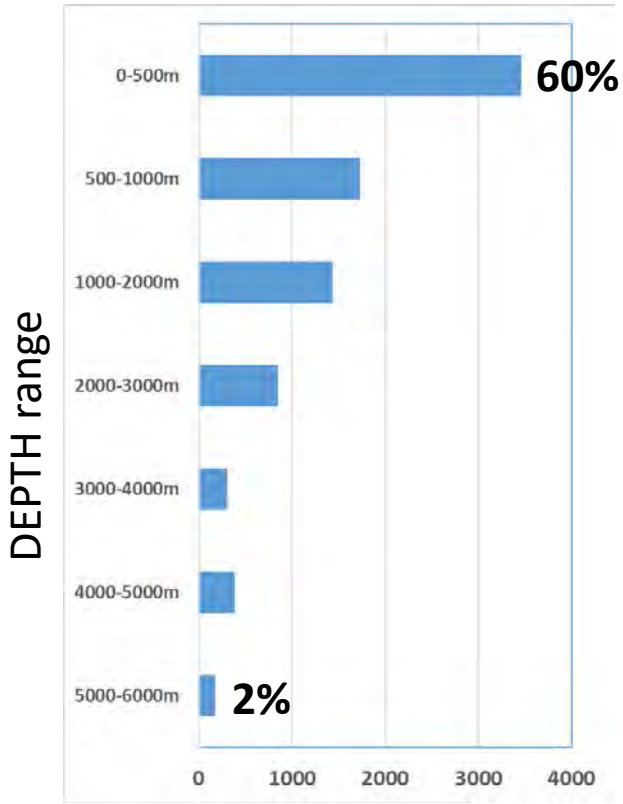

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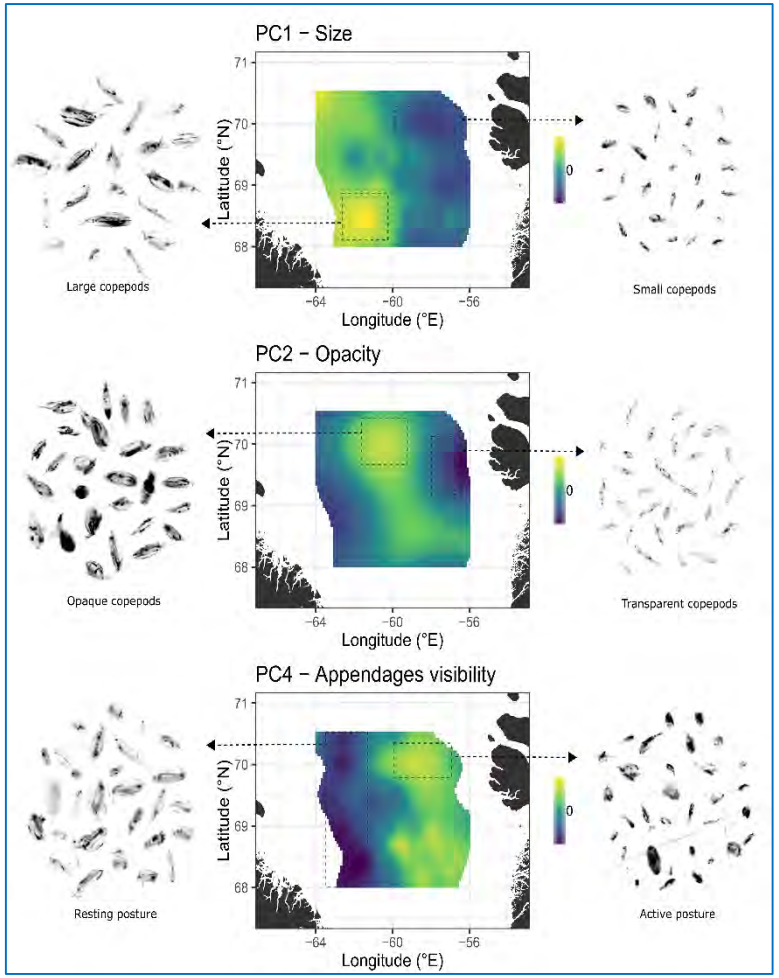
During the GreenEdge cruise, the UVP5 provided mean full information on the copepod behavior in the sea-ice zone such as feeding activity or sunlight protection.



Vilgrain, submitted.
=> Session HE41A @ 9:15 tomorrow

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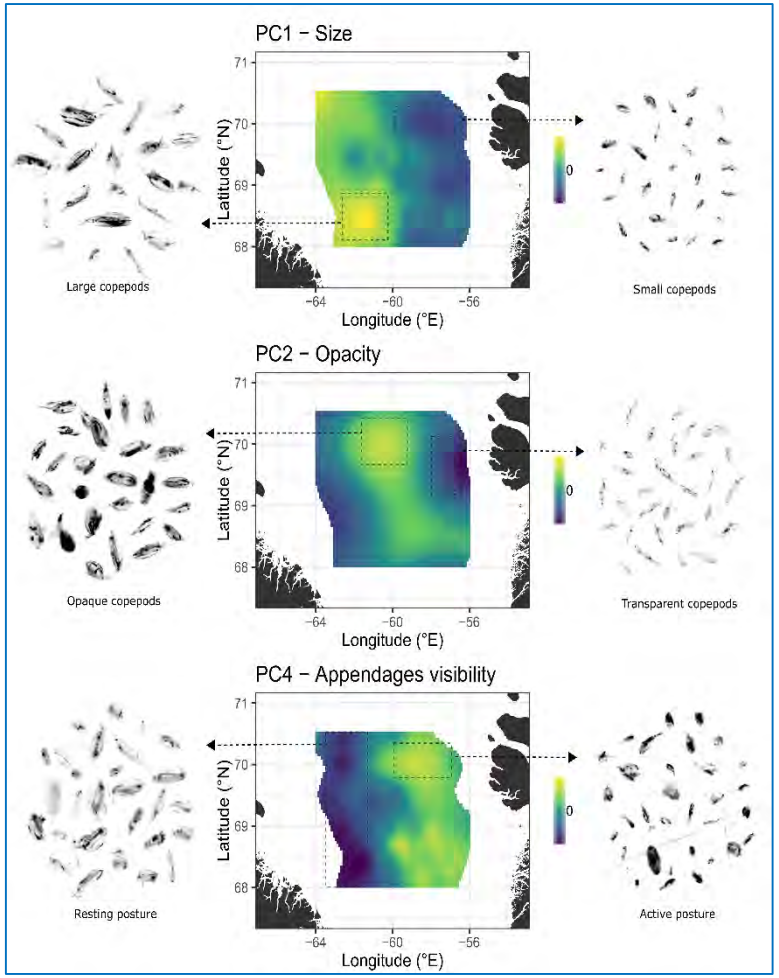

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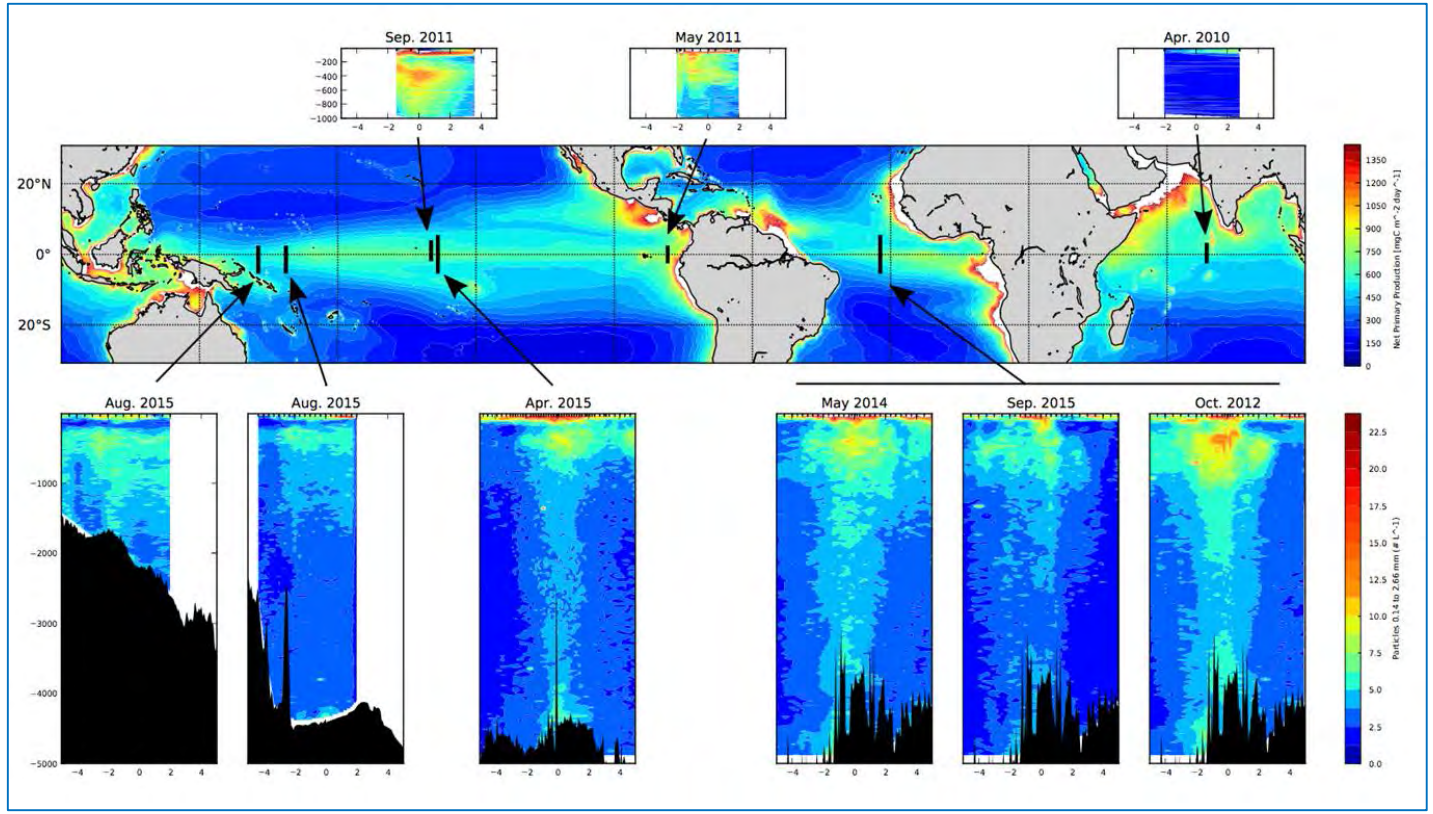
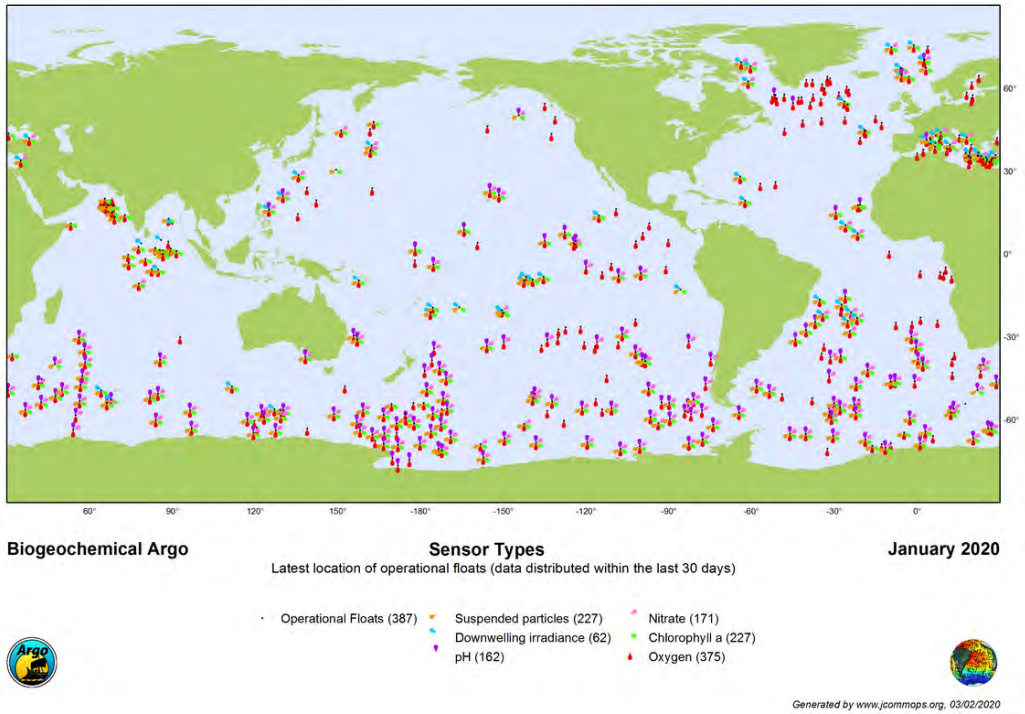
The UVP allowed to observe the LPM export down to 5000m and link it with the surface net primary production :

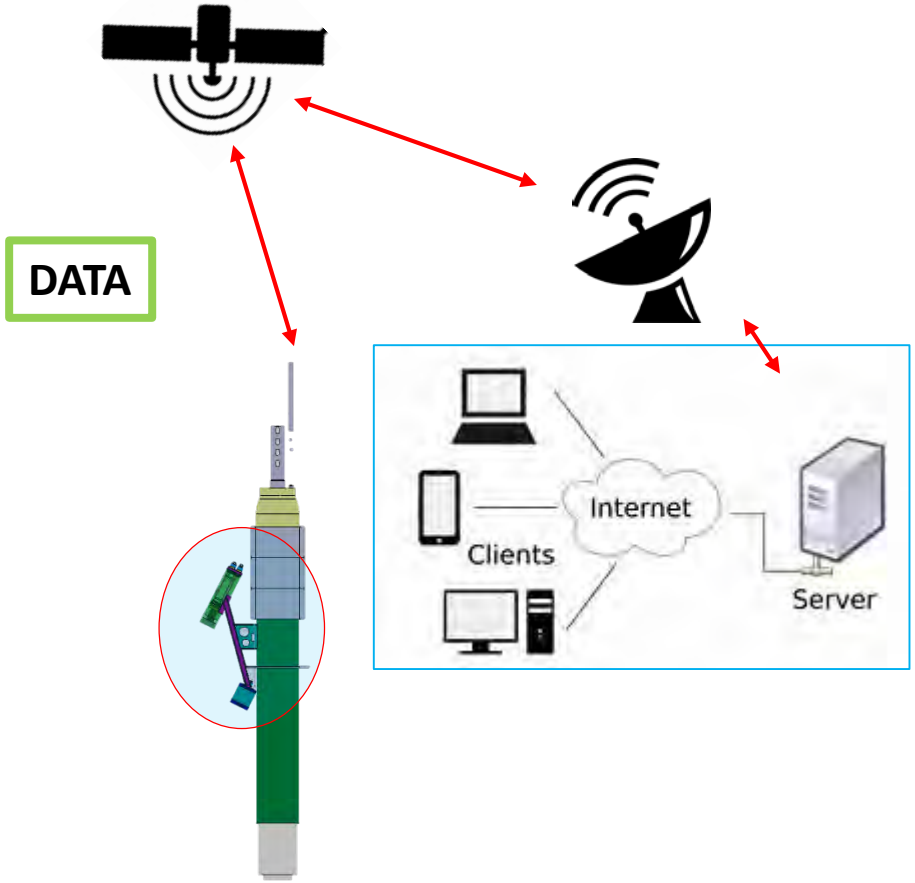
- 15000 km long
- 500 km wide
- 5 km high
- Probably the largest snow fall on earth



Kiko, Nature Geosciences, 2017

The dream at Villefranche/mer is to expand the UVP5 capability with a new version which could be embarked on most autonomous platforms (like floats) to allow high resolution studies and cover seasonal variability in remote places.





Claustre, Ann Rev Mar Sci 2019

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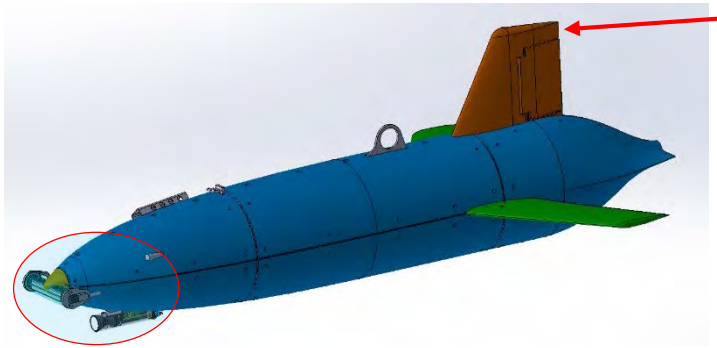
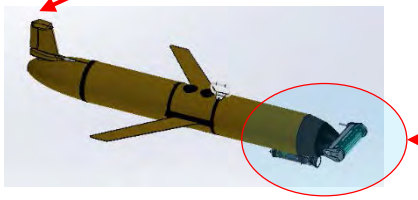
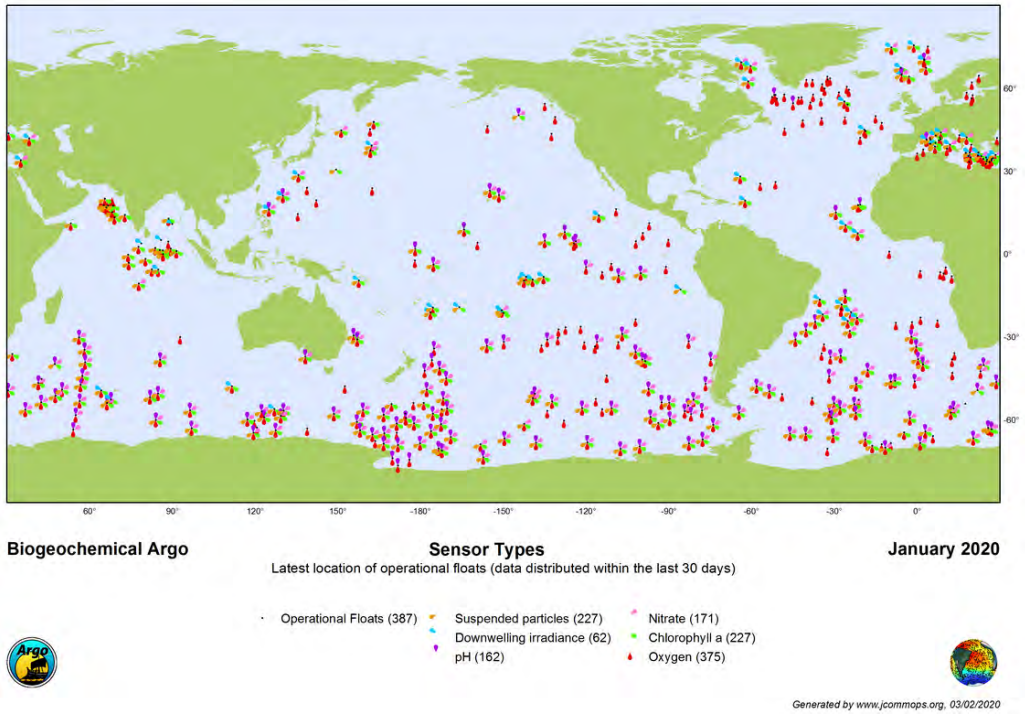
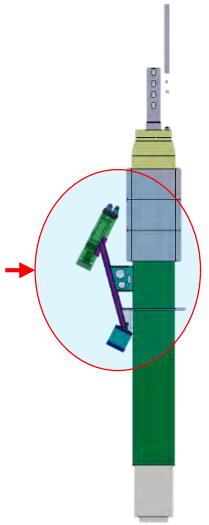
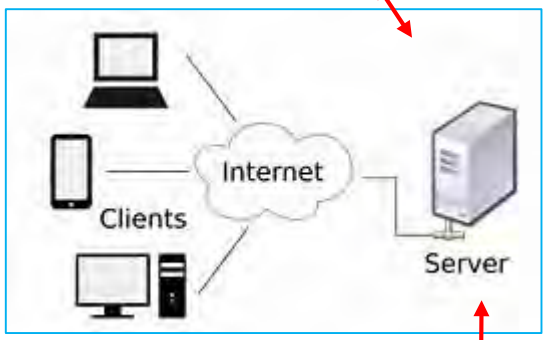






DATA





Raw DATA
IMAGES

Claustre, Ann Rev Mar Sci 2019

The **UVP6-LP** is designed for long endurance autonomous system : profiling floats, moorings, gliders, observatories…

Main specifications :

- < 3 kg (air)
- 6000 m
- 0.1Watt @ 0.1 Hz / 1Watt @ 1 Hz
- Low price (expendable)

- Same data quality than UVP5hd
- Reproductibility inter units
- Calibrated
- Embedded classification
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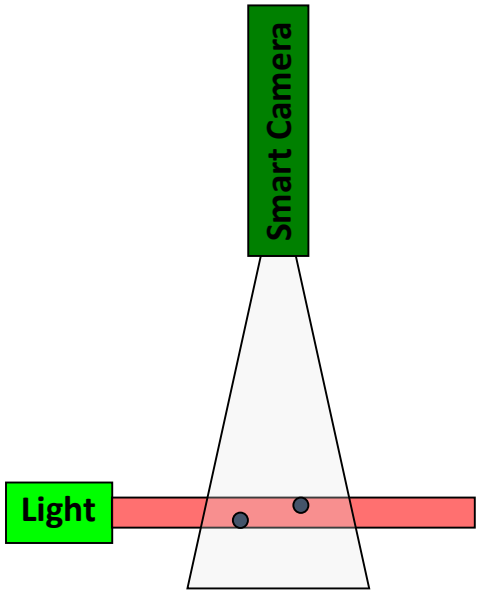
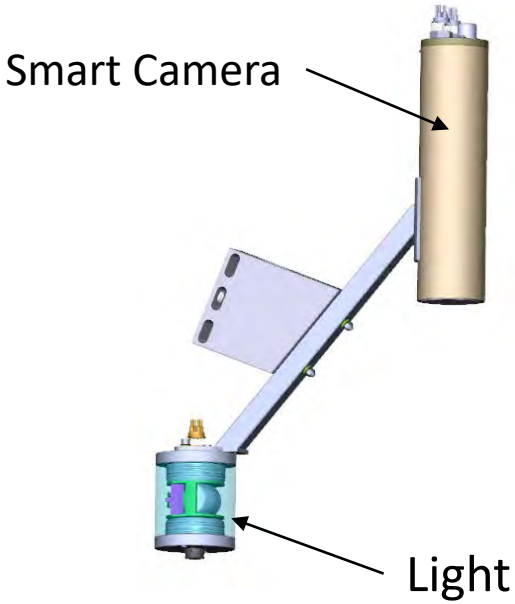
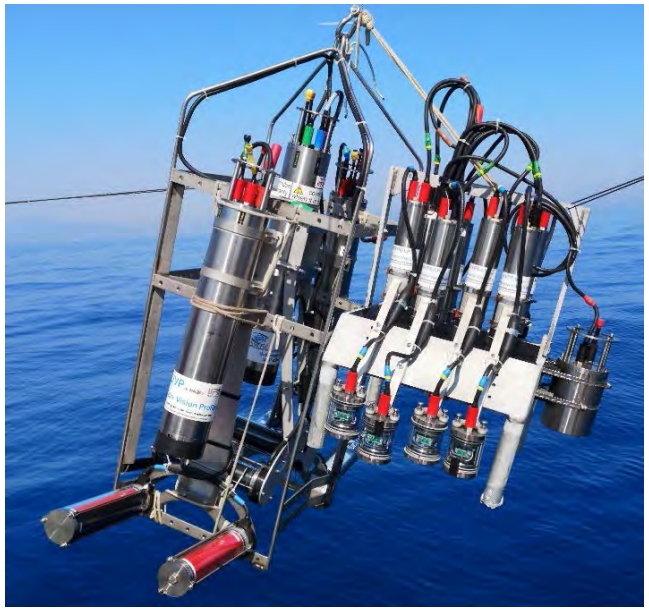


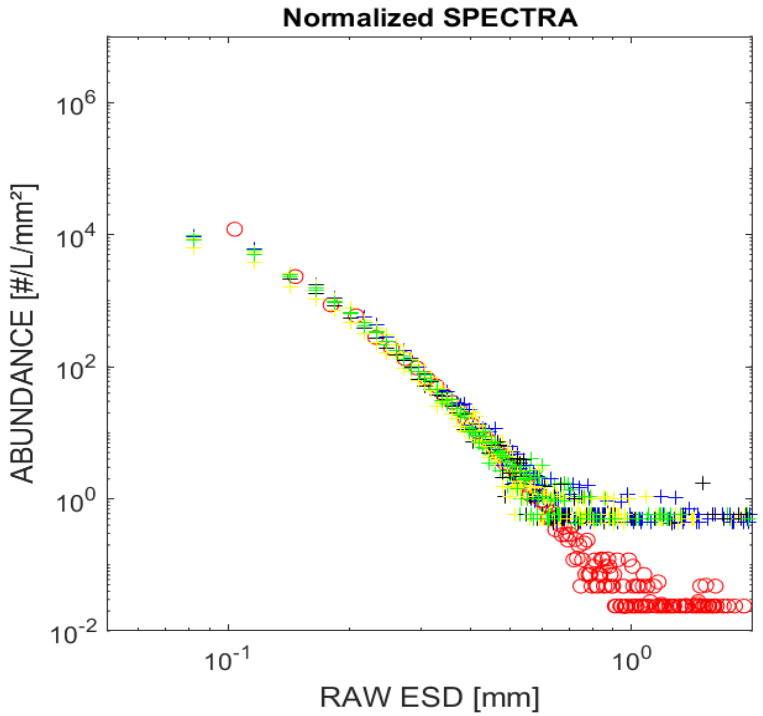


The **UVP6-LP** provides fully reproductible data.

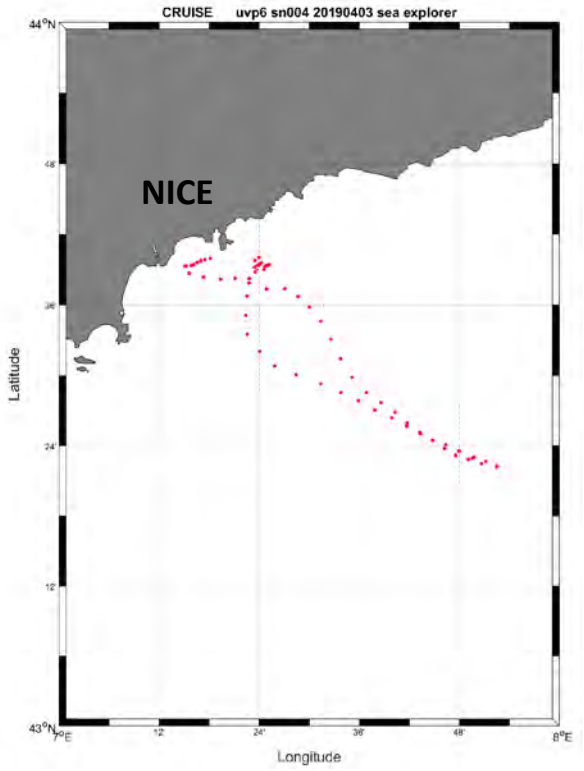
We field tested 17 units against 2 reference UVP5 and checked the homogeneity of their dynamic response.



Deployment of 8 UVP6 attached to 2 UVP5



The UVP6-LP is now integrated on the **SeaExplorer** and the **SeaGlider** gliders.
It performed a 7 day and 60 dives transect on the SeaExplorer off Nice last spring and recorded LPM data and images



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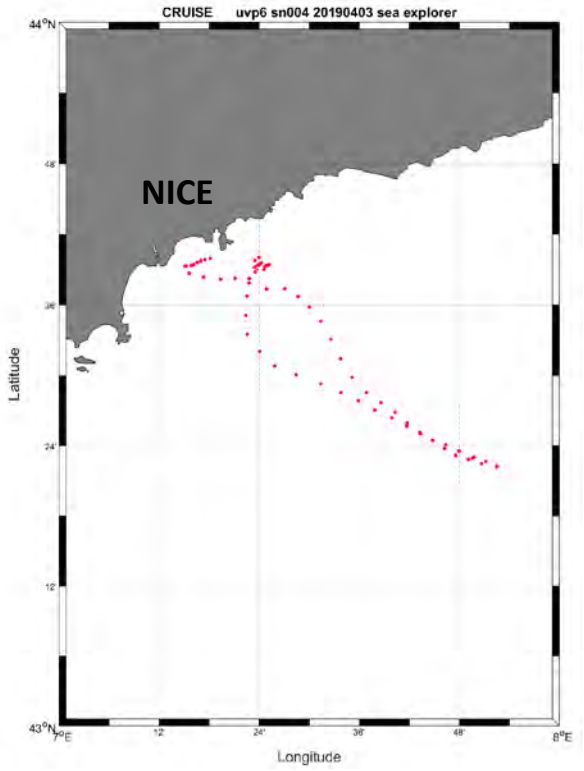

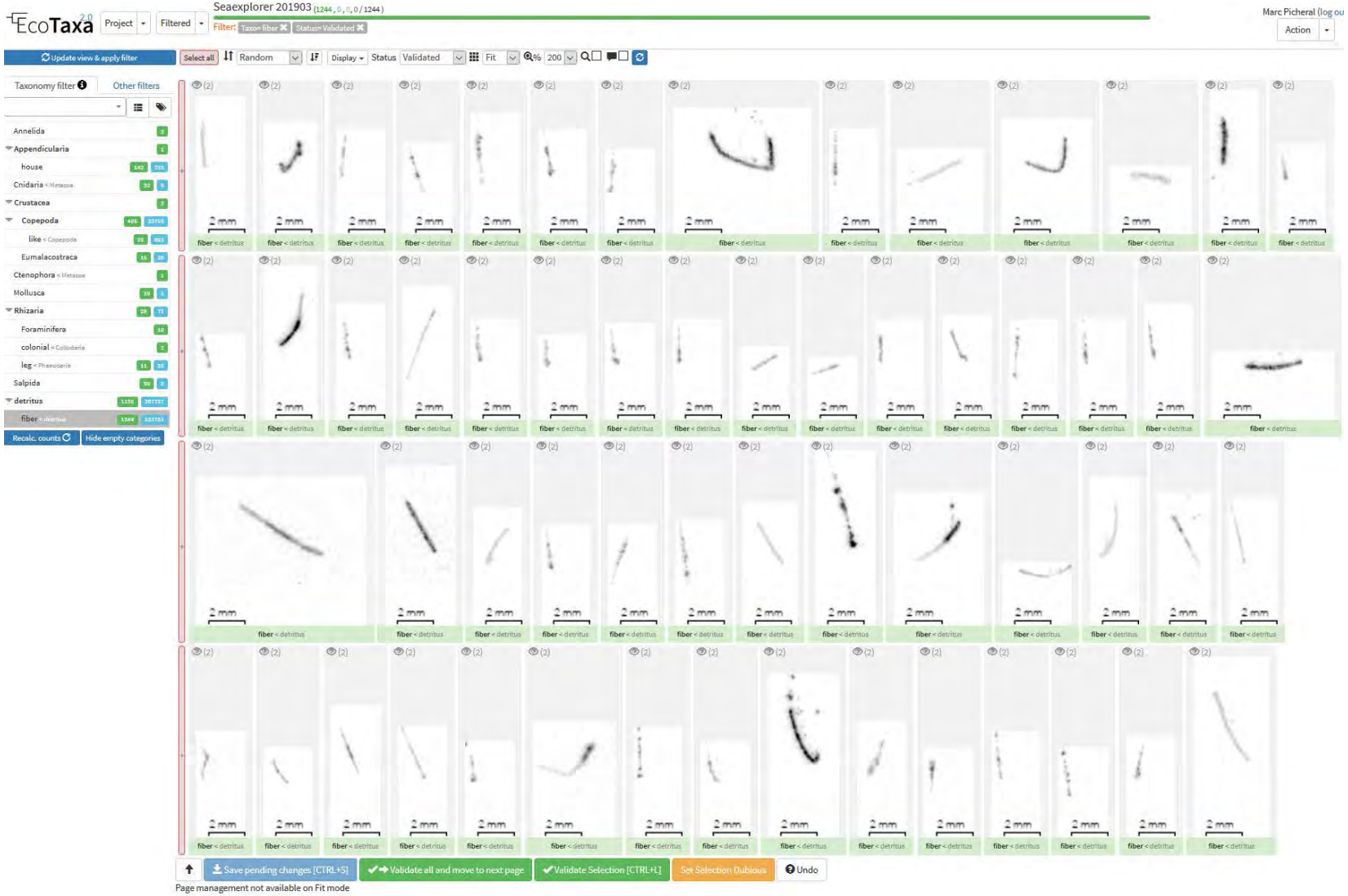

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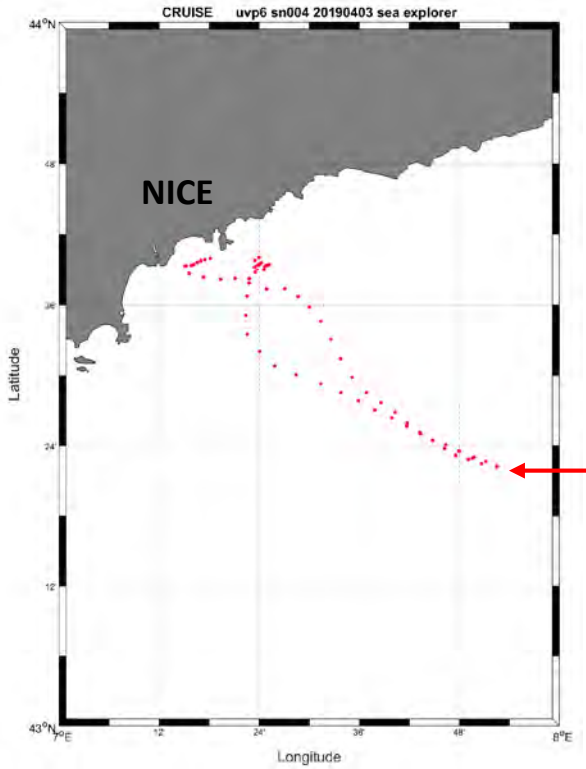
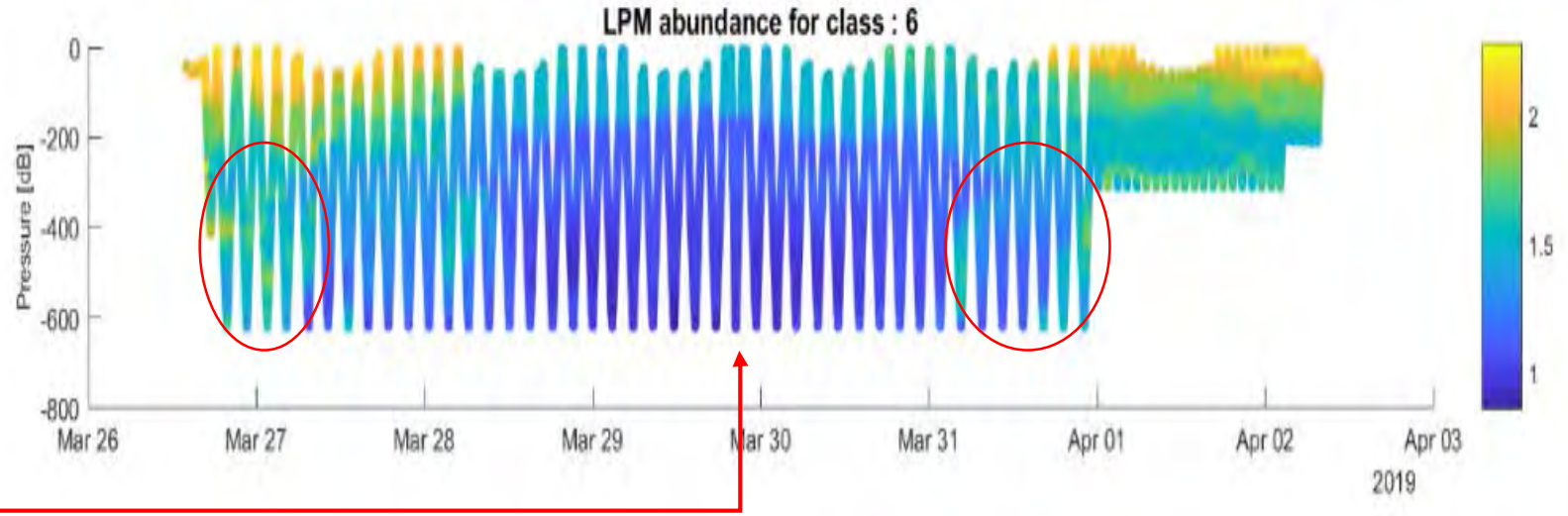
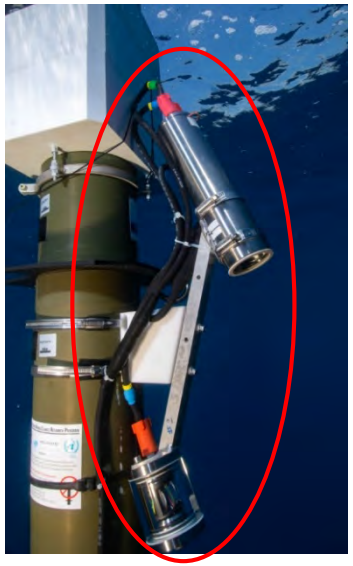




The **UVP6-LP** can be provided with the **NKE CTS5 BGC-Argo float**.
It performed a one month (29 profiles) endurance tests off Nice last June. The LPM data were transmitted in real time.



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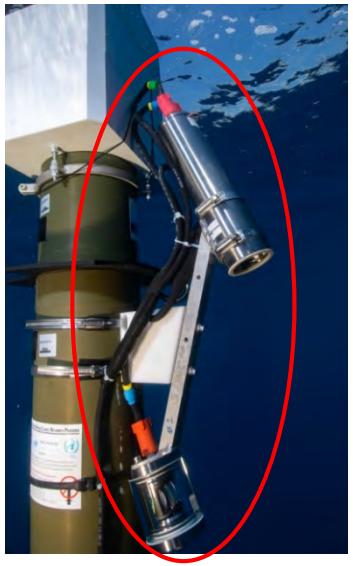
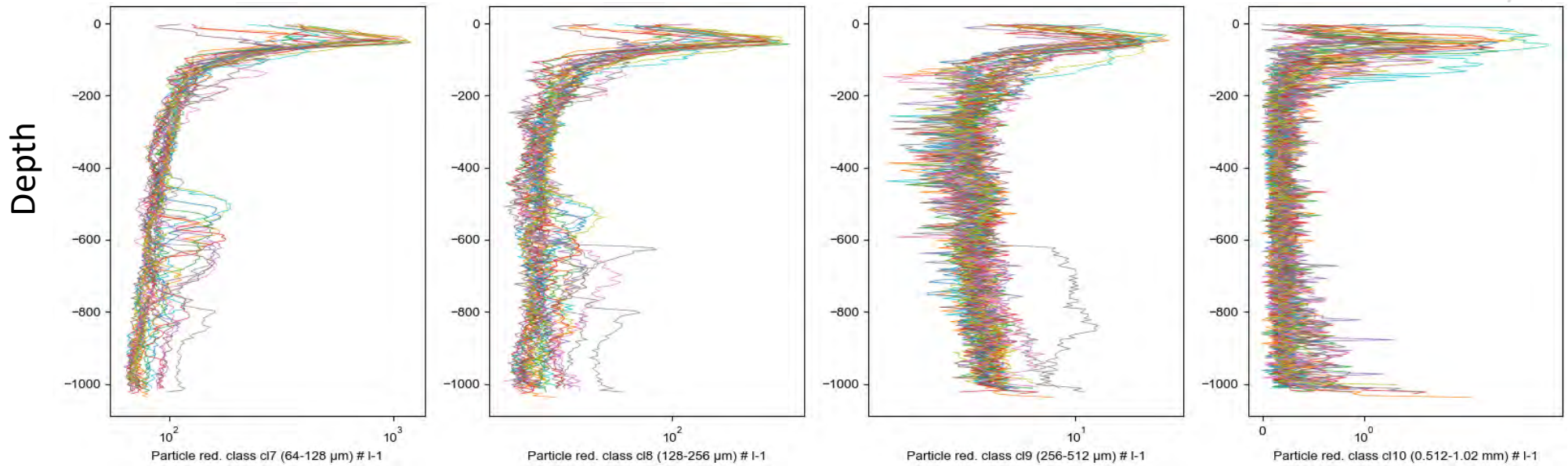
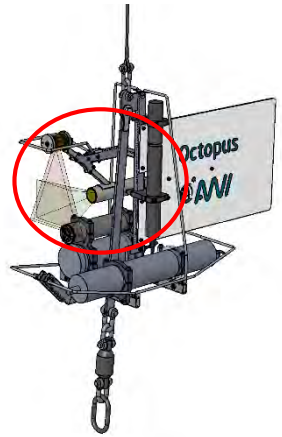




A UVP6-LP recorded 10 months of data and images (one image every 40 second) on a **mooring** by 82°N.



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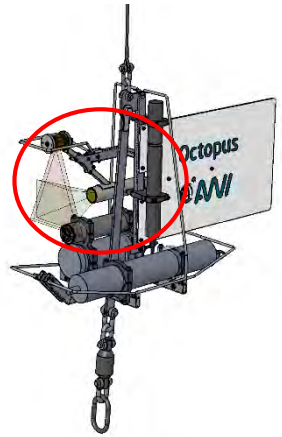
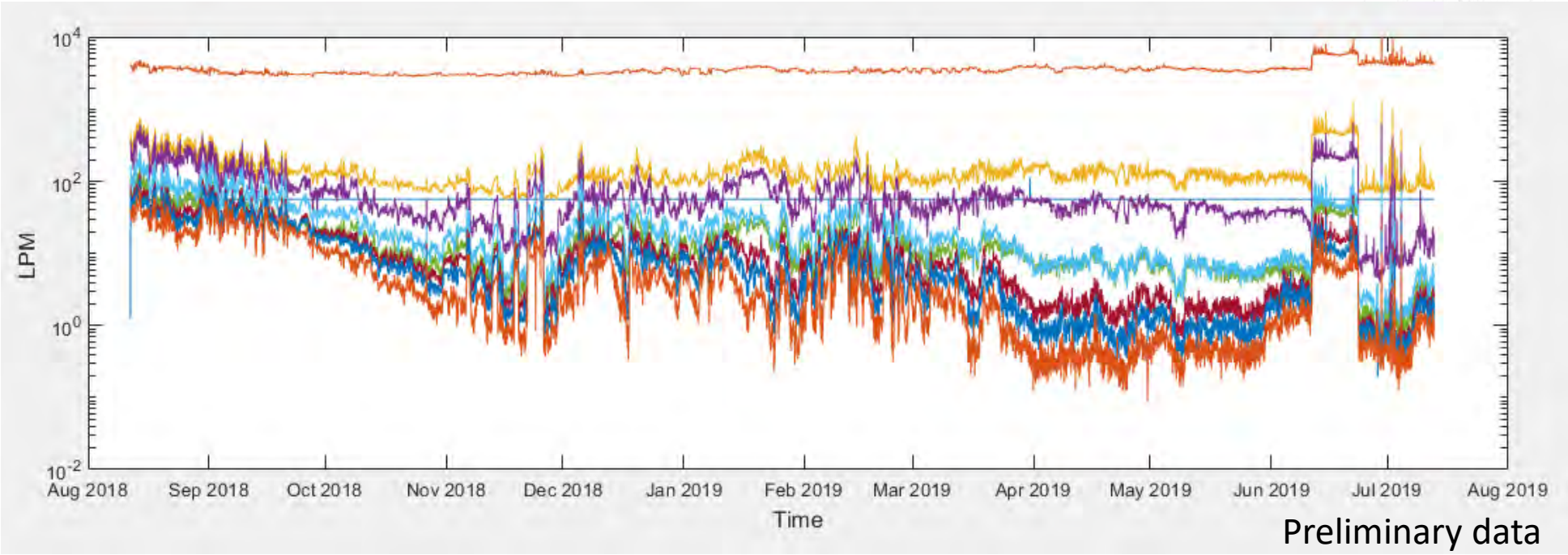
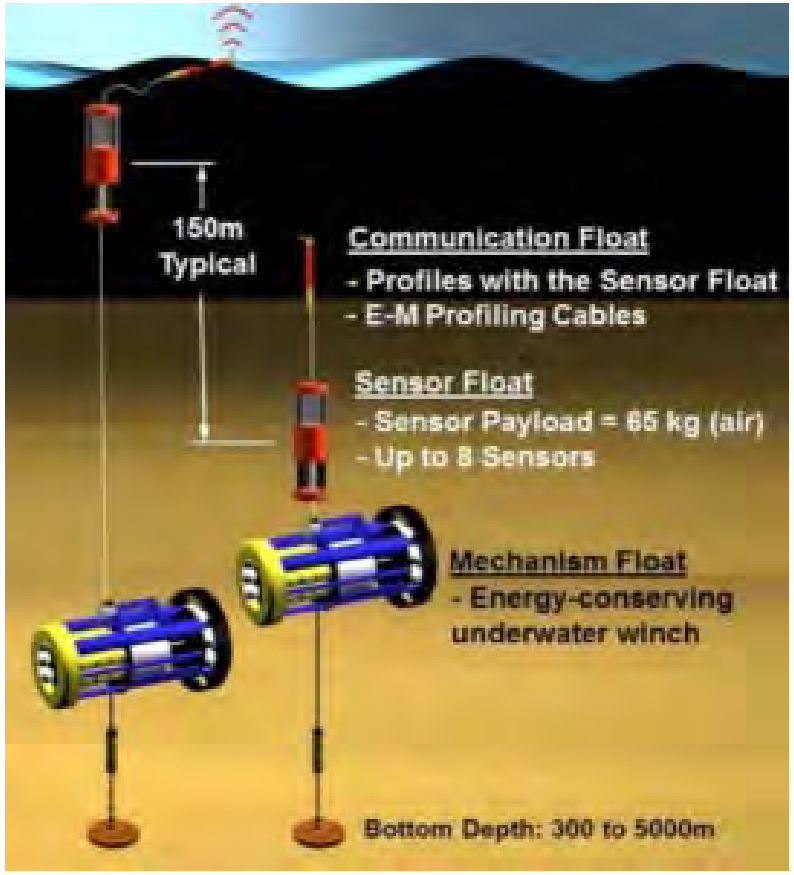
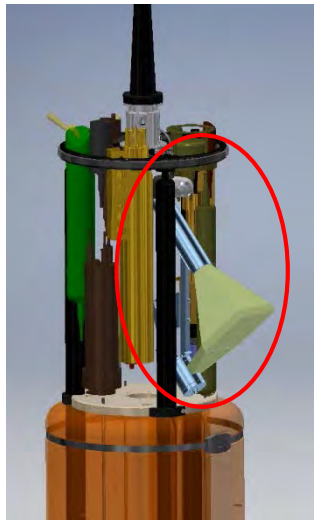




Preliminary data

The UVP6-LP was deployed last January on the **SeaCycler** sensor float by Dalhousie University.





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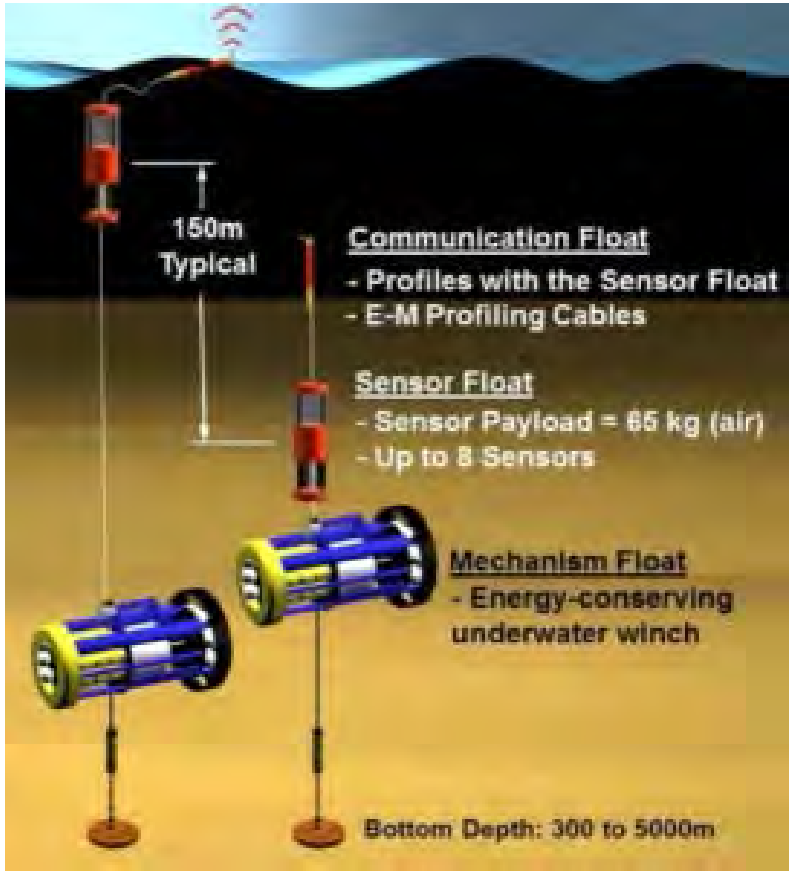
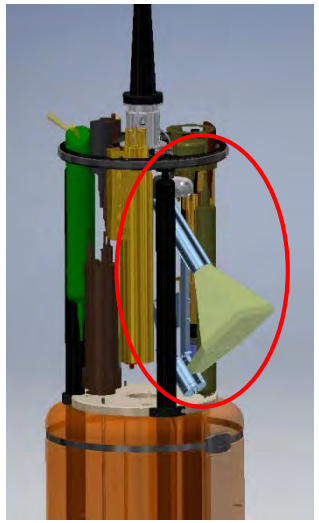
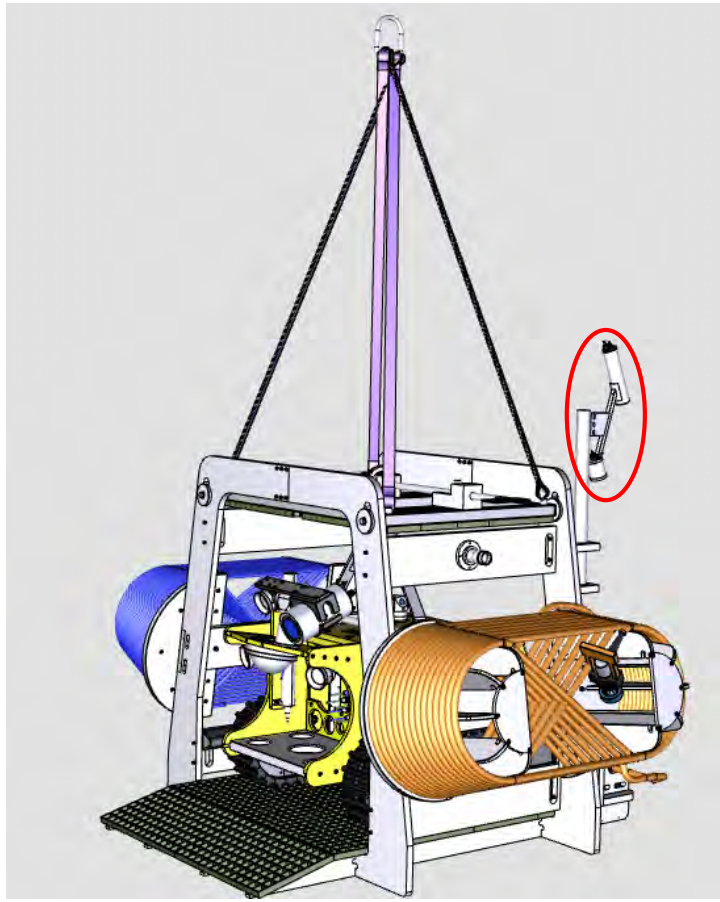




A UVP6-LP will be permanently deployed on the EMSO/ANTARES crawler cage by 2000m and connected to shore for real time control.



Poster 3344/IS34A

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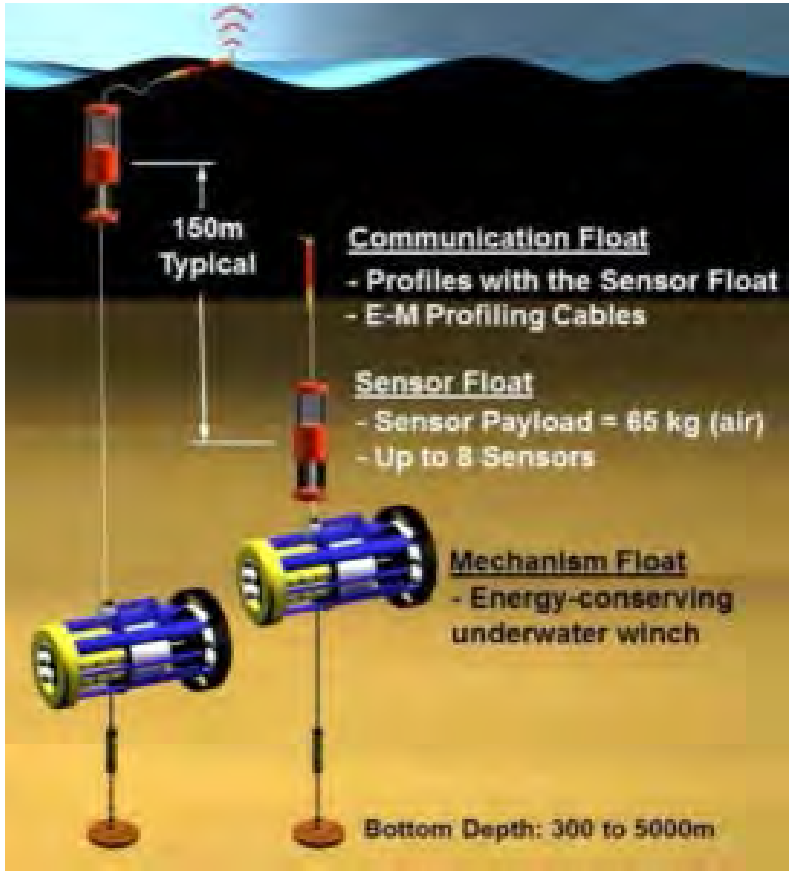

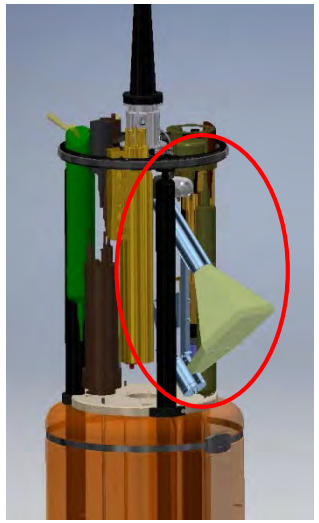

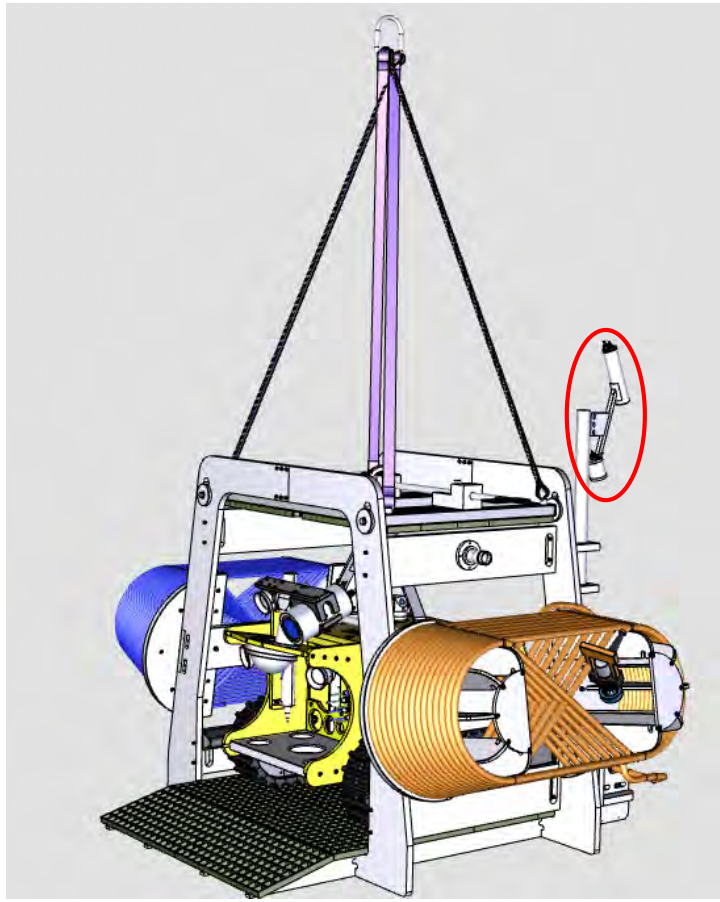

Poster 3344/IS34A

The UVP6-LP worked down at **4200m** depth on the **ROV KIEL6000** (GEOMAR) during a sea mining experiment.
Two units are recording and procesing image every 12 seconds during 18 month on a **mooring in the Tropical Atlantic**.

*Contrary to previous UVP5 on CTD-rosette frames, the **UVP6-LP** units deployed on **floats** will not be recovered at the end of their lives at sea. The numerous images collected during their upward journey of the float could not be transmitted to the satellite during the short time the float is at the sea surface.*
*Hence, the **embedded classification** of plankton and aggregates is mandatory onboard the floats because the images will generally not be available for later off-line classification.*

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TODAY :

- Classification score evaluated on UVP5 images using XGBoost : > 60%
- The code is implemented in the sensor and tools permits users to built classification models.
- Per **image** processing time :
  - Standard image acquisition and process : 700ms
  - If the image contains at least one object to classify:
    - Feature extraction for classification (per 1000 pixels) : 3ms
    - Loading classification model (20 class, 4000 trees) : 300ms
    - Classification : 48ms

1 second
0.8 watt

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In the **VERY NEAR FUTURE**, we will :

- Finalize a 20Hz (UVP6-HF) instrument for CTDs and AUVs
- Extend the detection size to phytoplankton
- Build a « universal » and reliable **classification models** for the EMBEDED CLASSIFICATION

  => The sensor will provide total and weighted (by classification score) **concentrations**, **opacity** and **size** of plankton and aggregates.

THANKS

https://ecotaxa.obs-vlfr.fr/
www.hydroptic.com/
www.wisip.com/
www.altidev.com/

The UVP6 is commercialized under **CNRS & Sorbonne University** licence by **HYDROPTIC** (booth 400, exhibition hall).
Its conception was possible thanks to the expertize of compagnies : **WISIP** (smart camera electronics and software), **ALTIDEV** (Ecotaxa and UVPapp) and the **COPL** from University Laval in Québec (optics).
The EC H2020 Bridges innovation program funded most of the development (grant agreement No 635359).

Marc Picheral[1], Emna Abidi[1], François Berry[2], Jerome Coindat[3], Denis Brousseau[4], Fabio Dias[5], Sylvain Fevre[3], Lionel Guidi[1], Jean Olivier Irisson[1], Louis Legendre[1], Fabien Lombard[1], Antoine Manzanera[6], Laurent Mortier[6], Laurent Navarro[7], Laura Picheral[1], Lars Stemmann[1], Simon Thibault[4] and Thierry Tixier[5],

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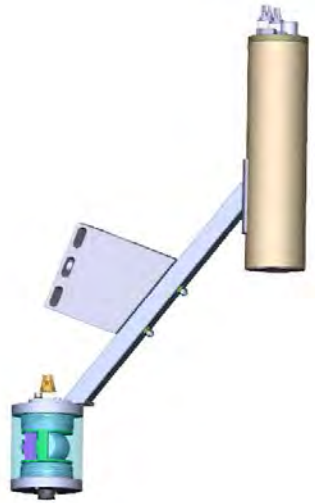
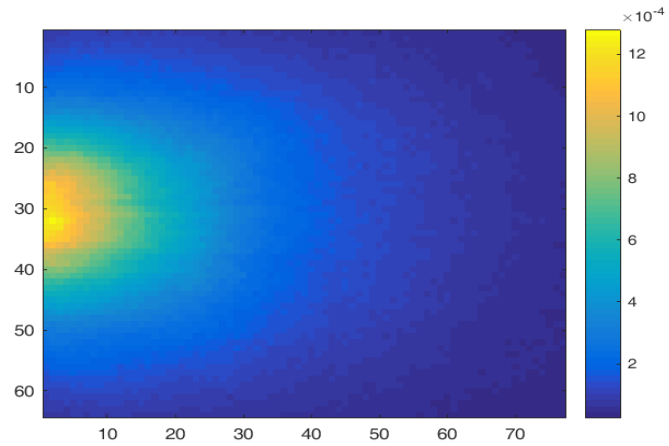
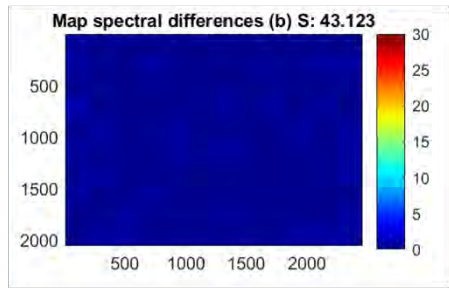
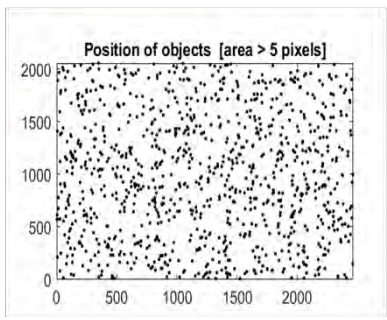
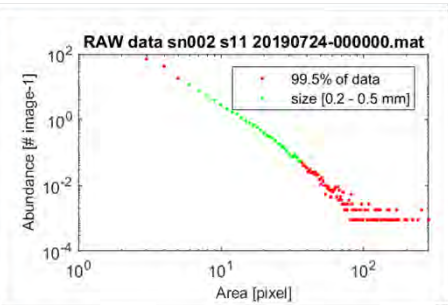
2) Institut Pascal - UCA CNRS, Aubiere, France,
3) Hydroptic, l'Isle Jourdain, France,
4) Université Laval, Center for Optics, Photonics and Lasers, Laval, Quebec, Canada,
5) WISIP, Clermont Ferrand, France,
6) ENSTA Paris, Institut Polytechnique de Paris, Palaiseau, France,
7) ALTIDEV, Plaisance du Touch, France

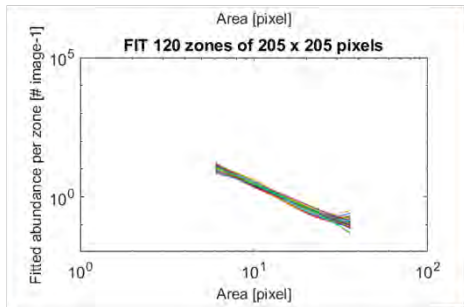



×10^-4
12
10
8
6
4
2
10
20
30
40
50
60
10
20
30
40
50
60
70

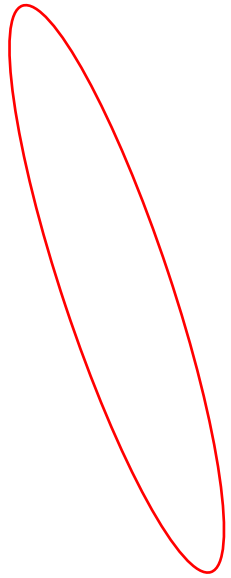

Map spectral differences (b) S: 43.123
500
1000
1500
2000
500
1000
1500
2000
30
25
20
15
10
5
0

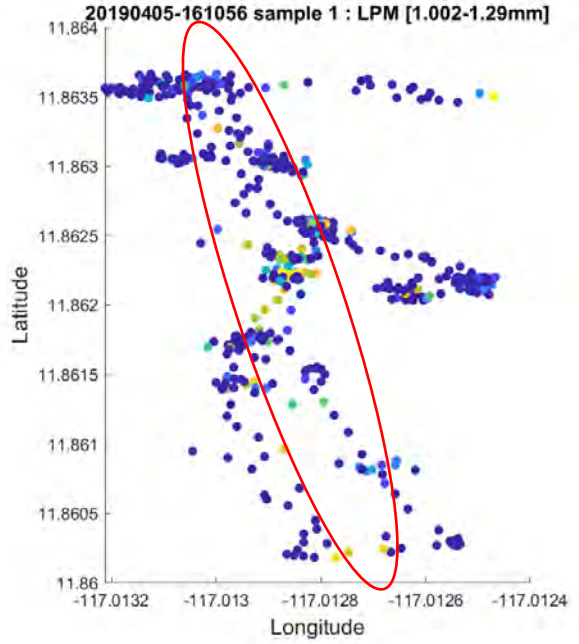

Position of objects [area > 5 pixels]
2000
1500
1000
500
0
0
500
1000
1500
2000


RAW data sn002 s11 20190724-000000.mat
99.5% of data
size [0.2 - 0.5 mm]
Abundance [# image-1]
Area [pixel]

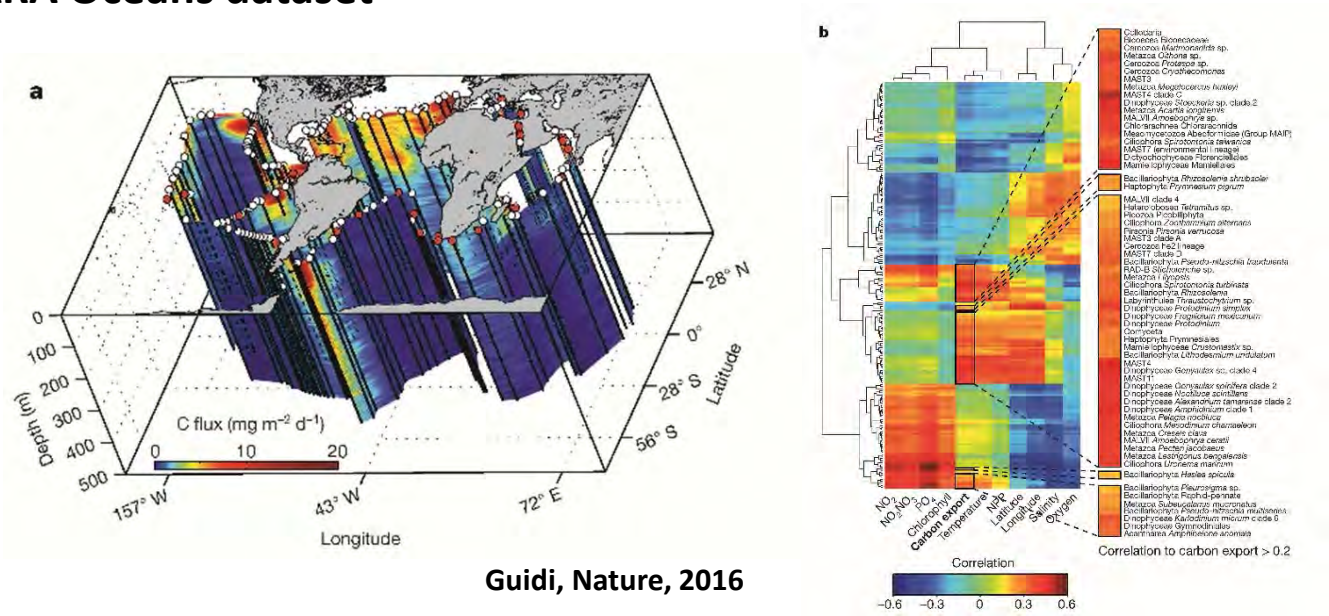

Area [pixel]
FIT 120 zones of 205 x 205 pixels
Fitted abundance per zone [# image-1]
Area [pixel]

Achieved test : deep sea mining experiment (ROV Kiel 6000 GEOMAR)



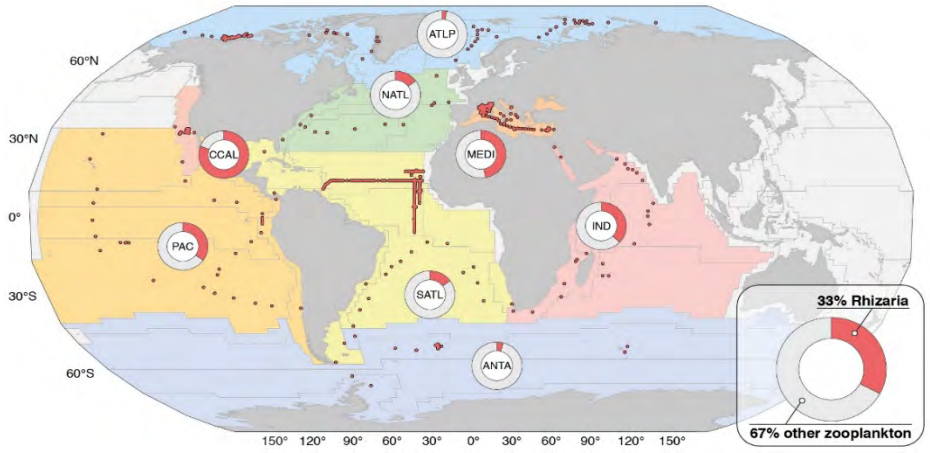


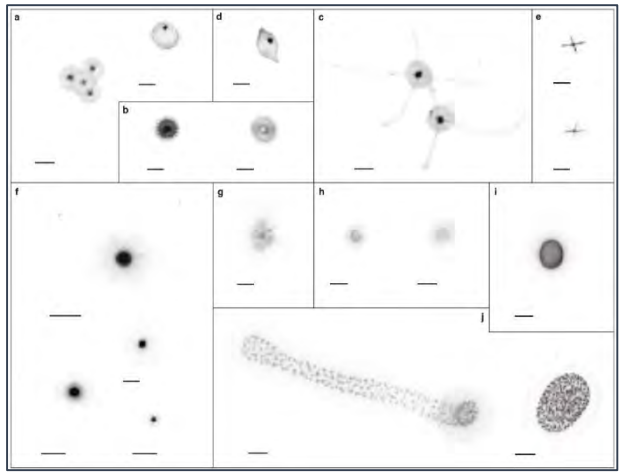
TARA Oceans dataset



Guidi, Nature, 2016

The carbon export down to 500m can be linked to plankton assemblages inferred from DNA.

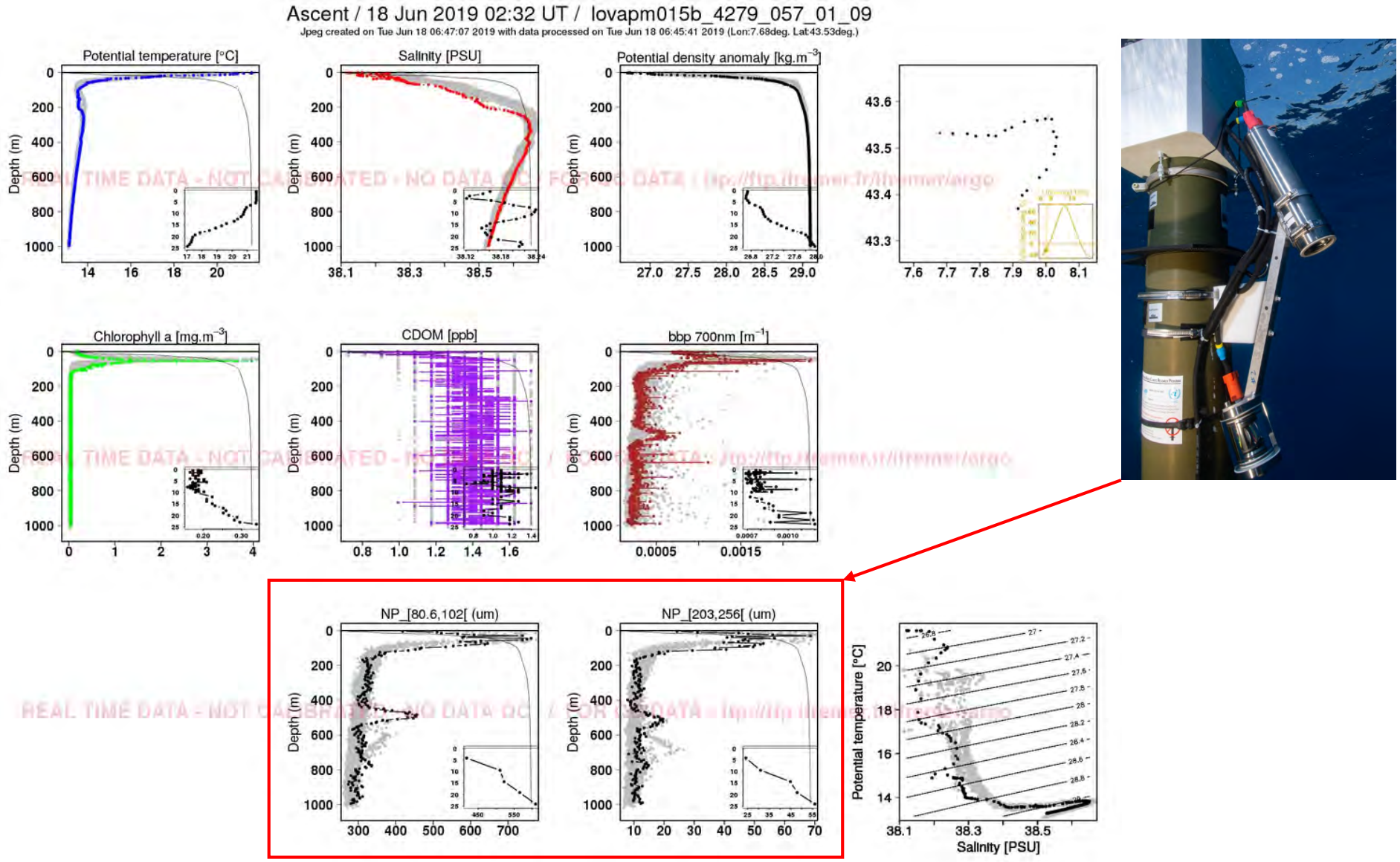


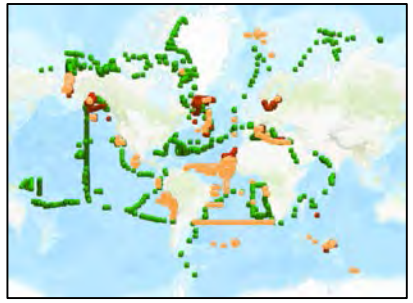


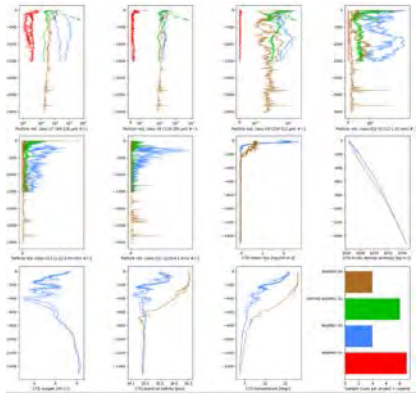
Biard, Nature, 2016

The UVP5 revealed the abundance of the fragile unicellular rhizarians in the first 1000m of the oceans

Achieved test : Profiling float CTS 5 (LOV)







PROJET(s)

EcoPart

(serveur/mobile)

EcoTaxa 2.0

- Saisie metadata mission
- MAJ metadata capteur (si nécessaire)
- Extraction descripteurs vignettes
- Soustraction du bruit / imageOK

- Transfert bases mobile-serveur
- Gestion Predicted/Validated
- Données temporelles
- Recalcul après modif metadata capteur
- Contrôle Qualité

Récupération automatique sur le serveur ARGO

Vecteur (flotteur) ARGO (données au format NetCDF ARGO)

- Métadonnées (capteur et mission)
- Données synthétiques (Histogrammes de taille + gris)
- Données de bruit
- Identification des objets (prédiction)
- Données CTD

Table CSV brute traduite au format Ecopart (manuel)

Vecteur lambda (données au format du vecteur)

- Métadonnées (capteur et mission)
- Données synthétiques (Histogrammes de taille + gris)
- Données de bruit
- Identification des objets (prédiction)
- Données CTD

Récupération capteur

Import (type Zooprocess)

MODULE
- Traitement LPM
- Traitement images

Raw data (données issues de la carte SD de UVP6 via Ethernet)

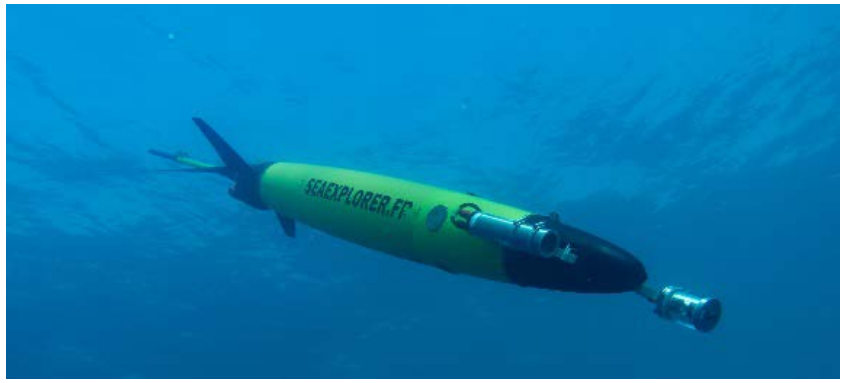
- Métadonnées (capteur)
- Données brutes (nb + gris/pixel_size) + bruit
- Vignettes
- Données CTD

MODULE PILOTAGE :Interface graphique permettant de:
- Créer une architecture dossier compatible avec Ecopart
- Configurer un UVP6 (hardware, acquisition, taxo)
- Télécharger des données via Ethernet
- Convertir les images

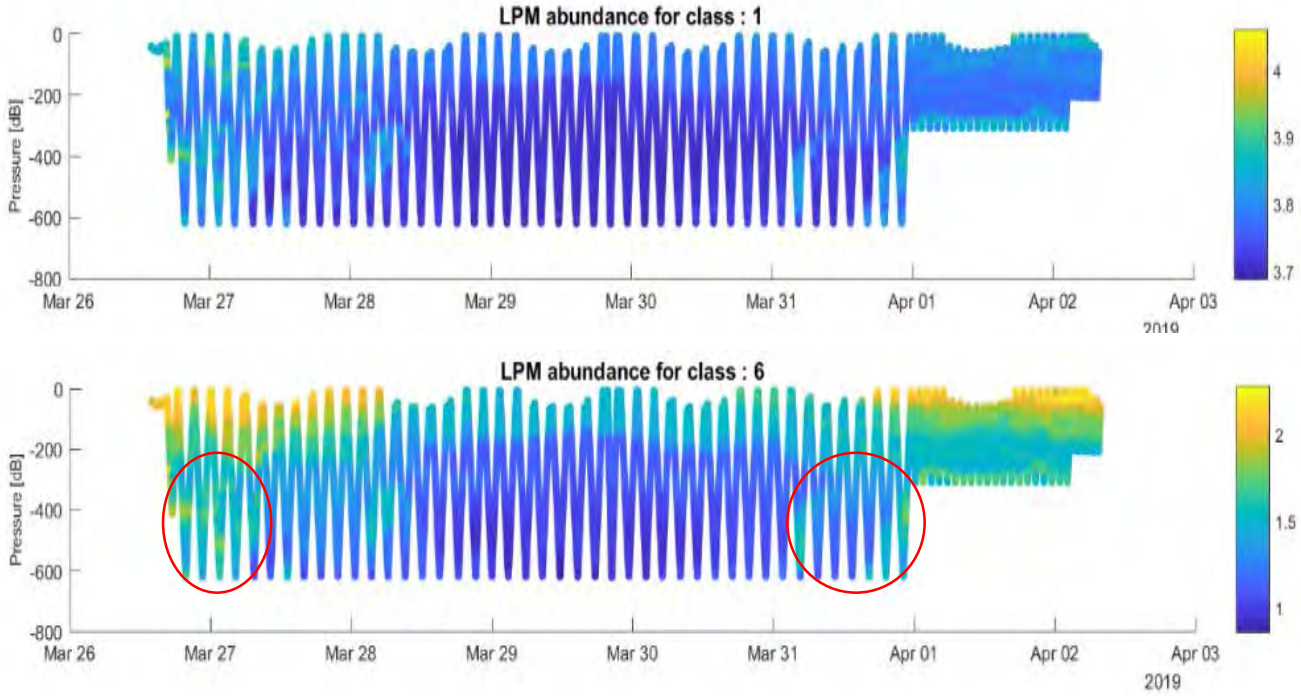
BASE DE DONNEES
capteur : UVP5-6

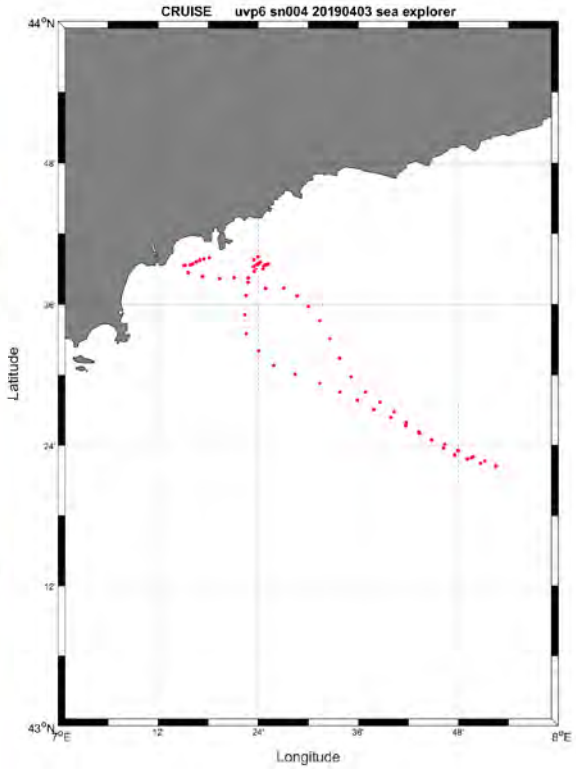
Achieved test : Sea Explorer (Alseamar)

- Field trial 26/03/2019 – 02/04/2019
- 60 dives 600m - Dyfamed



LPM data



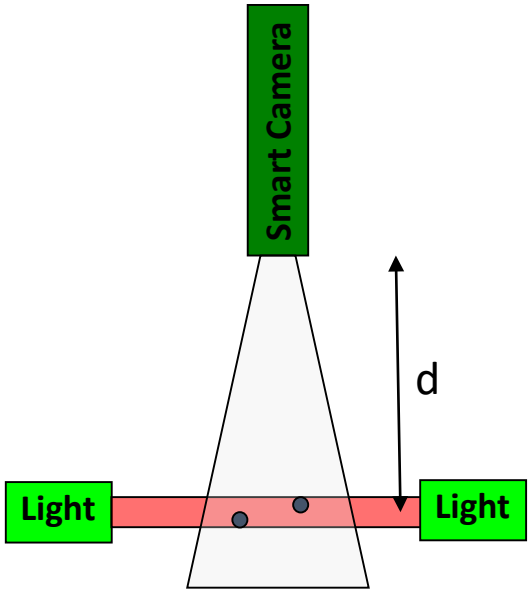


The **Underwater Vision Profilers** are **in-situ camera** to:

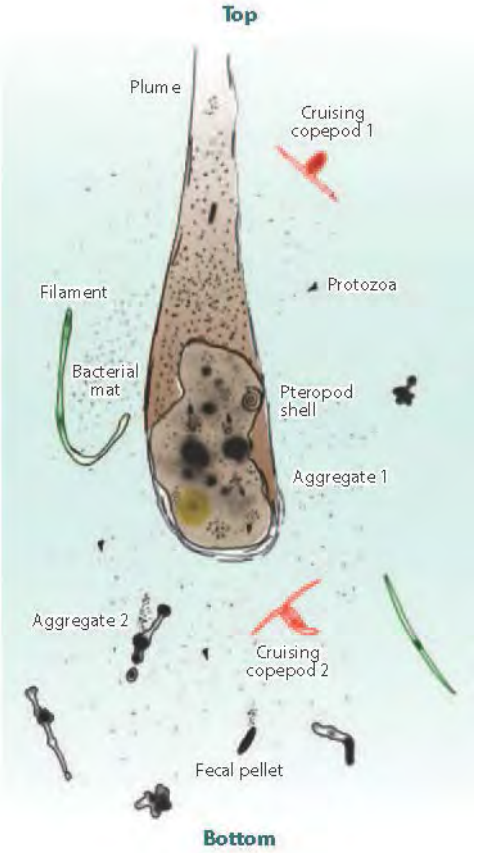
- **Count and size large particles** > 0.1 mm ESD
- **Identify plankton and aggregates** > 0.5 mm ESD

The instruments are utilized for :

- **Particle monitoring , biogeochemical studies (including carbon pump)**
- **Plankton ecology**



- **Constant distance between camera and objects > size measurements**
- **Volumetric image > concentration**



Stemmann, *Annu. Rev. Mar. Sci. 2012*