Adaptive observing strategies for fine scale biophysical interactions

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Collaborations :

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and the BIOSWOT and SWOT-AdAC teams

The importance of phytoplankton diversity

- Resilience of ecosystems

- Diversity of the trophic web

- Patrimonial value

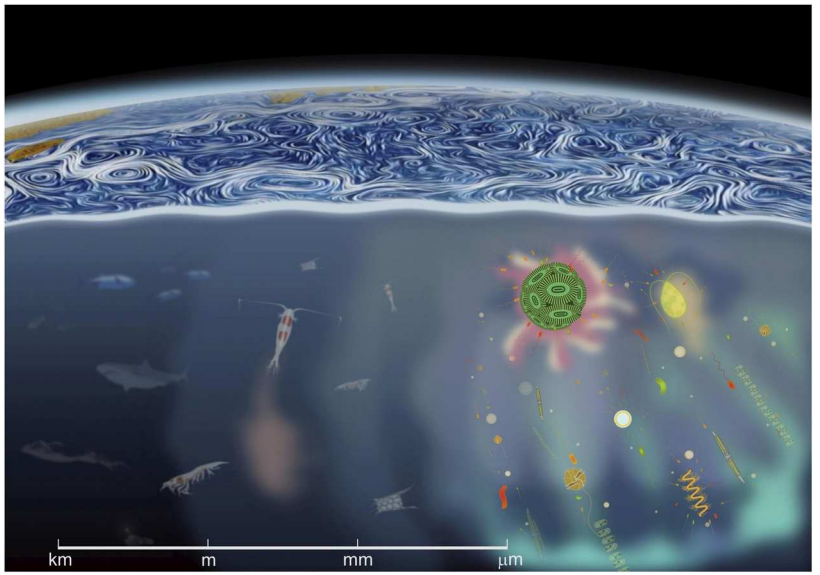
Credits: Tara Oceans

The "**Paradox of the Plankton**" (Hutchinson 1961)

A limited range of resources supports
an unexpectedly wide range of plankton species :

the competitive exclusion principle is not respected !?!

Possible explanations :
- vertical gradients of light ;
- symbiosis or commensalism ;
- differential predation ;
- turbulence and constantly changing environmental conditions.



From Basterretxea et al., 2020

Indeed, a big knowledge gap remains: the ocean finescale

The 50's

The “discovery” of ocean variability by drifting buoys

The Swallow floats : isopycnal floats with acoustic positioning

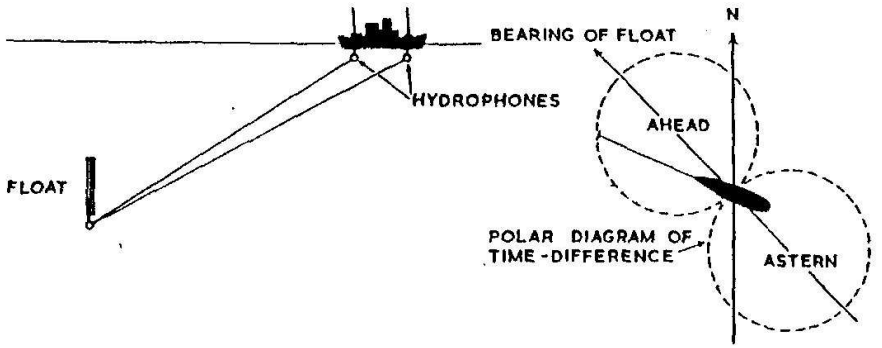


Fig. 3. Method of locating float.

http://www.po.gso.uri.edu/rafos/general/history/index.html

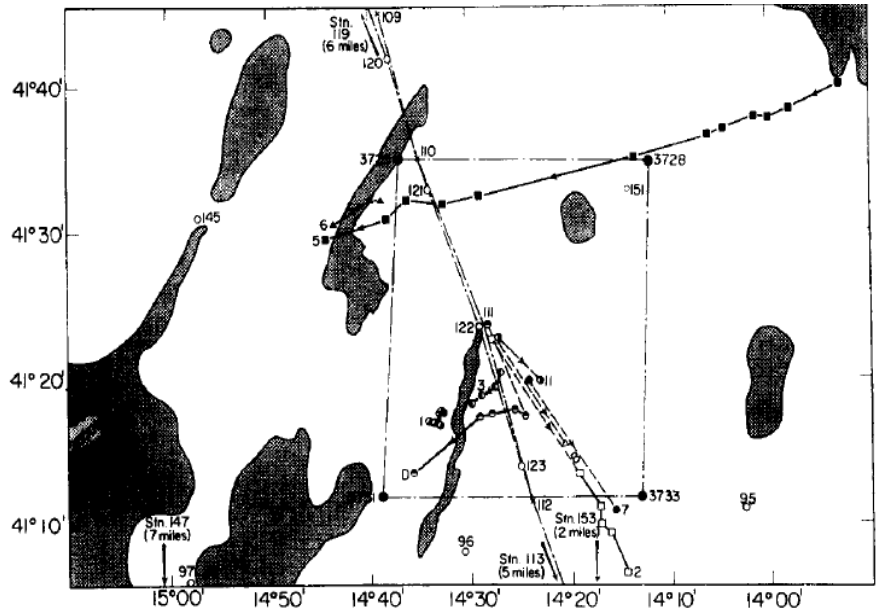


Fig. 2. Tracks of the floats, and positions of hydrographic stations. The dashed sections of the float tracks are shown on a larger scale in Fig. 3.

Swallow et Hamon (1959)

*“The **currents** were found to be **variable in time** with periods of a few weeks, **and in space** over a distance of a few tens of miles. In a vertical section, velocities did not decrease uniformly with depth, and **no ' level of no motion' was found**.”*

The 80's

Lagrangian observations of the first mesoscale vortices (Allen, Bob, etc.)
by drifting buoys and satellite images

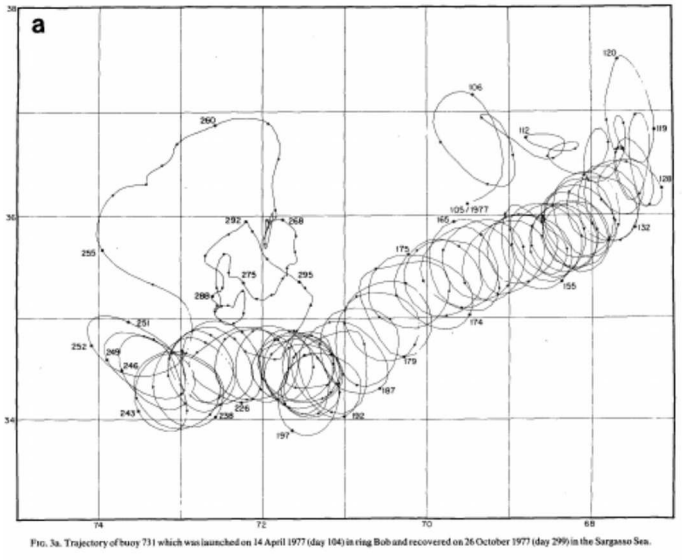


FIG. 3a. Trajectory of buoy 731 which was launched on 14 April 1977 (day 104) in ring Bob and recovered on 26 October 1977 (day 299) in the Sargasso Sea.

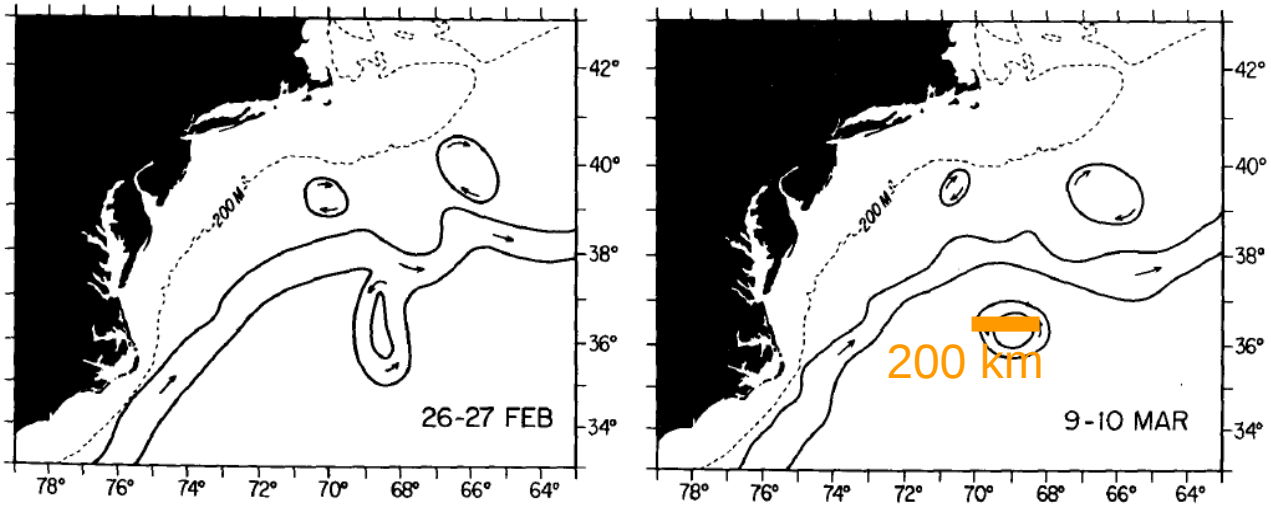


FIG. 1a. Schematic diagram showing formation of Gulf Stream ring Bob, February–March 1977, based on infrared images from the NOAA 5 satellite. Two anticyclonic rings were observed north of the Gulf Stream.

RAFOS floats

Richardson et al., 1979,80, 83

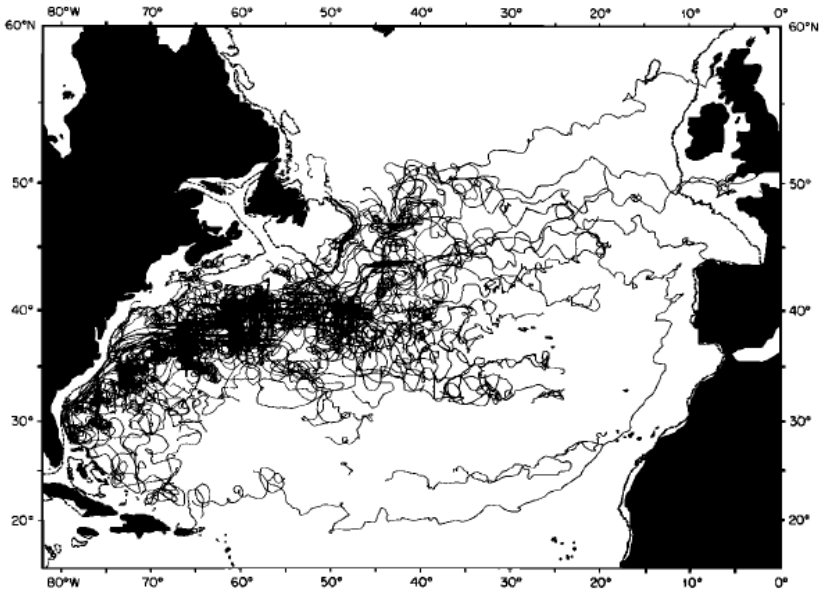


Fig. 2. Summary plot of 110 free drifting buoy trajectories (1971–1981). Buoy data were generously contributed by many individuals (Table 1).

Numerical modelling

Semtner (1995): "...oceanographers became aware of the **immensity of their task**...it is extremely helpful to **invoke the simulation capability** of supercomputers to improve understanding of basic processes and their interconnectedness, as well as to help interpret sparse observations."

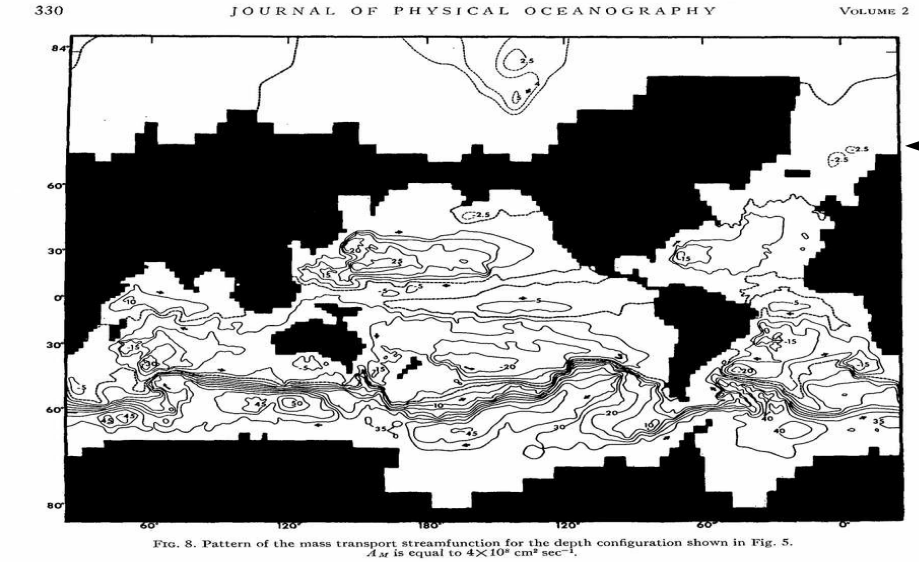

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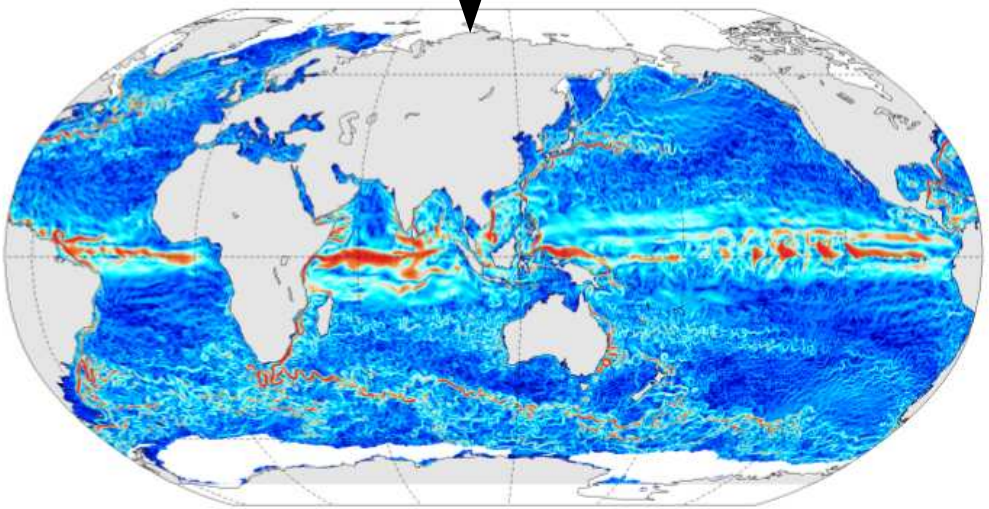
FIG. 8. Pattern of the mass transport streamfunction for the depth configuration shown in Fig. 5. A_M is equal to 4×10^5 cm^2 sec^{-1}.

Brian & Cox 1972
Premier modèle global

Drakkar group 2017

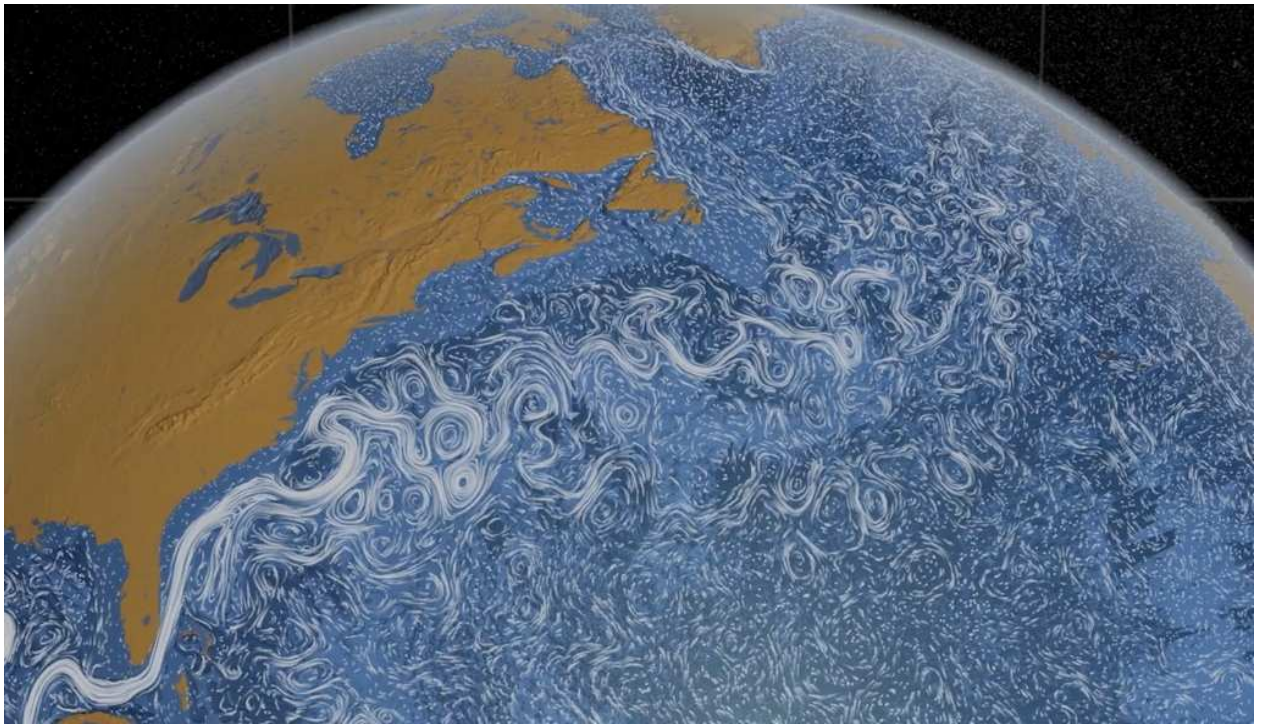


Snapshot of velocity at the surface in the ORCA12 ocean model.
A. Lecointre and J.M. Molines, LGGE, France

Rapid evolution : models
"Eddy permitting"
then
"Eddy resolving"

+
regional HR modelling

Combining in situ measurements & numerical modelling & remote sensing...



Perpetual Ocean *https://svs.gsfc.nasa.gov/3827*

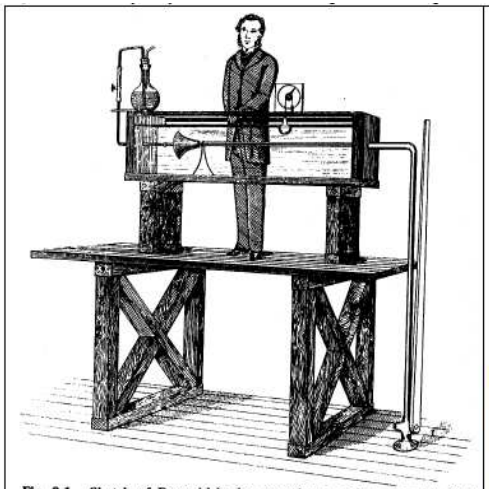


Fig. 9.1. Sketch of Reynolds's dye experiment, taken from his 1883 paper

http://www.marine.maine.edu/~eboss/classes/SMS_491_2003/Week_5.htm

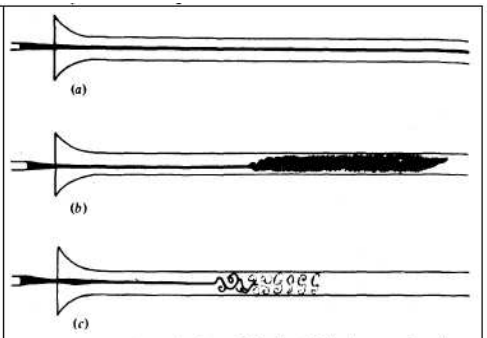


Fig. 9.2. Reynolds's drawings of the flow in his dye experiment.

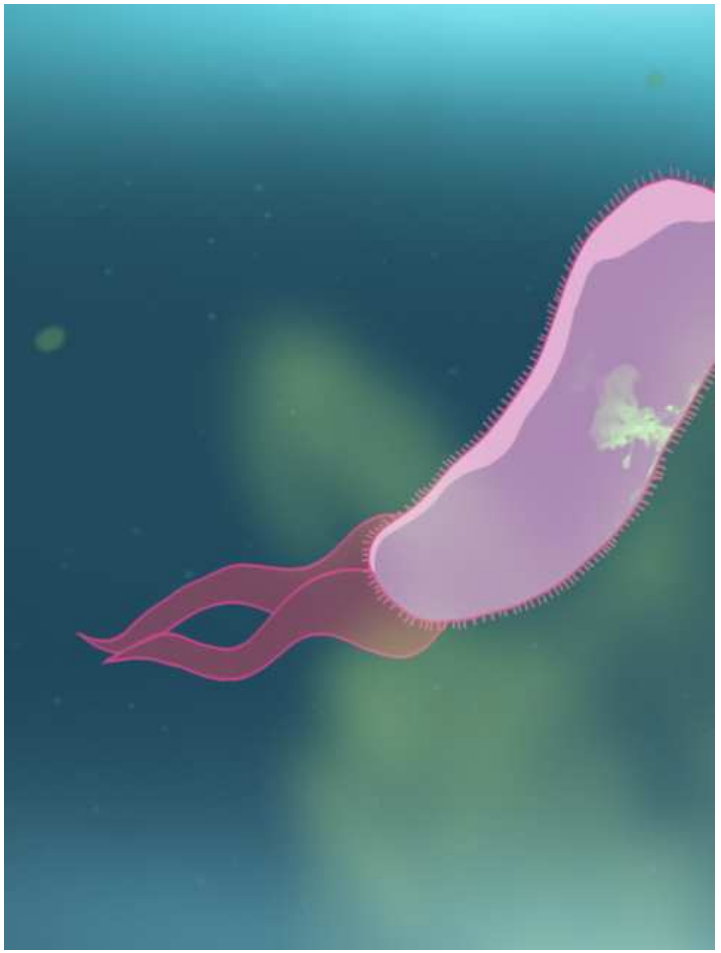
His results were as follows (Fig. 5):

1. At low velocities the streak of dye extended in a straight line along the tube.
2. If the water in the tank was not at rest, the streak would shift about the tube.
3. As the velocity increased, at some point in the tube, the color band would all at once mix up with the surrounding waters. When viewing the tube with an electric spark, this mixed fluid actually looked like a bunch of coherent eddies.

An undeniable turbulent behavior!

The marine microbes

1974
Importance of marine microbes in marine food webs and dissolved material cycling first recognized.

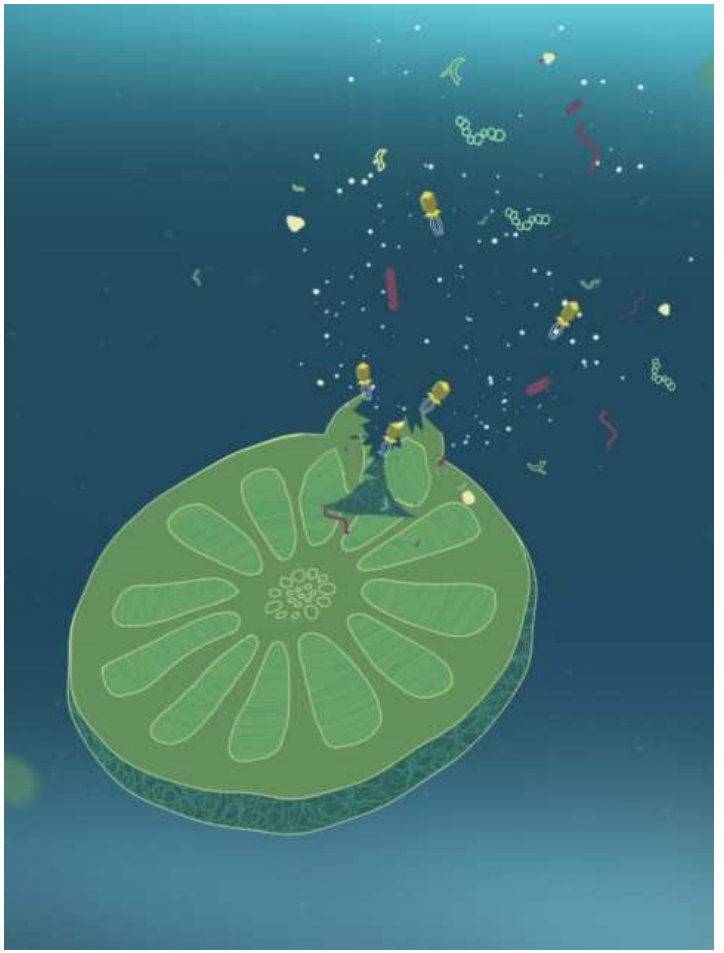


The microbes absorb dissolved molecules…

and they reject others when they die.

The so-called

Microbial loop



Images from Smithsonian Institution
https://ocean.si.edu/milestones-marine-microbiology

The marine microbes

1979

Waterbury observes **Synechococcus** bacteria in the Arabian Sea.
It is present in large quantities almost everywhere in the ocean and is found at the base of the food web of fish and large mammals.

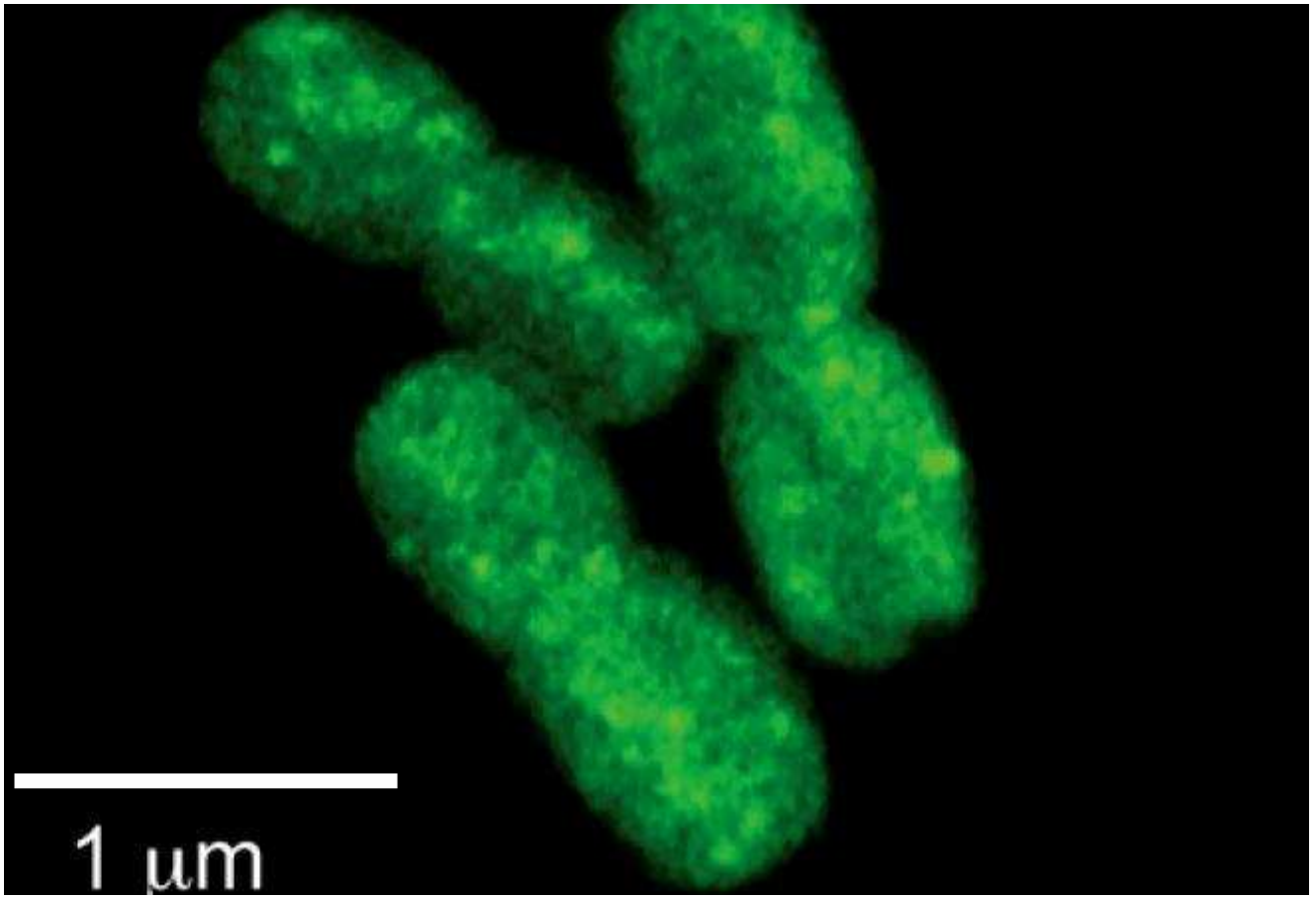


Image du Pacific Northwest National Laboratory
https://ocean.si.edu/milestones-marine-microbiology

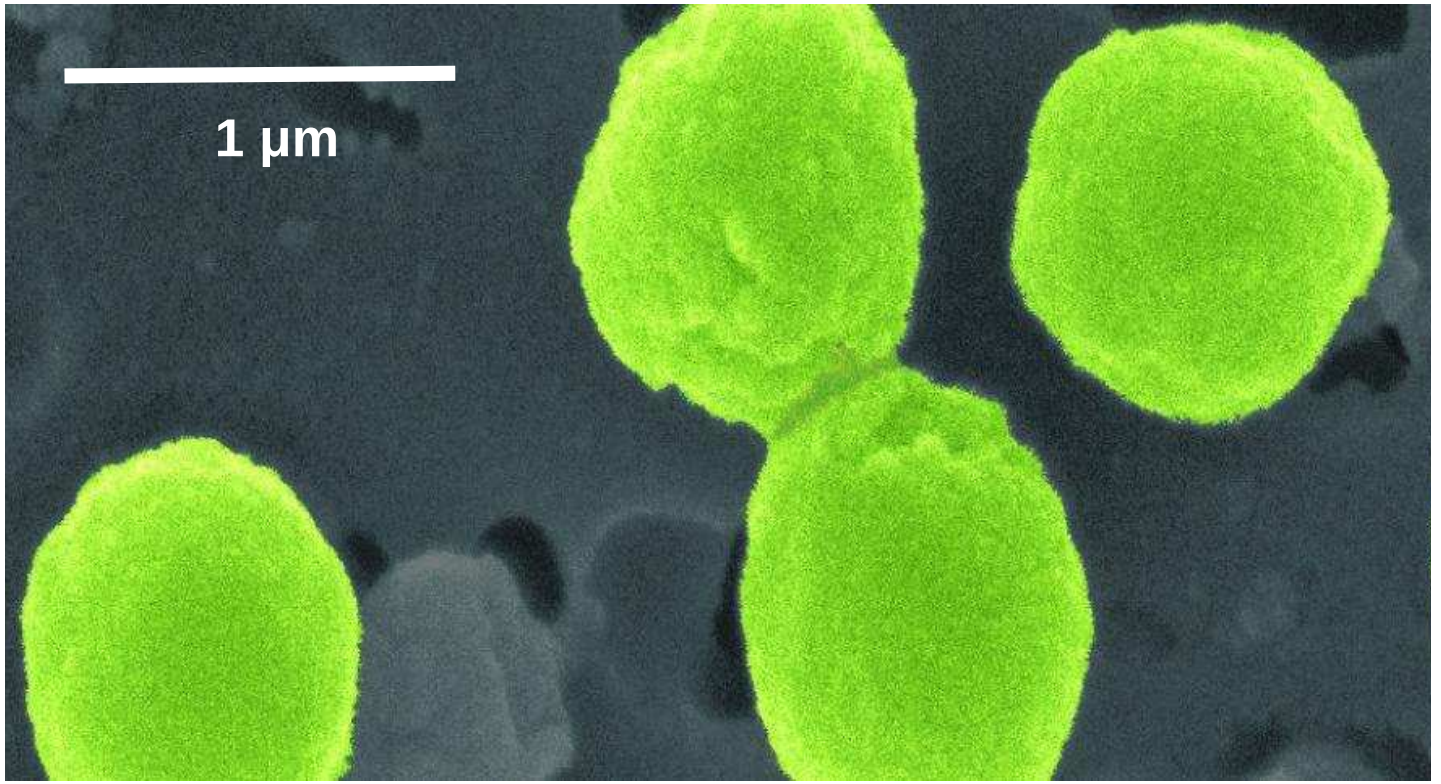
1 µm = 0,000001 m
= 10^{-6}m

Diameter of
a hair:
50 µm

The marine microbes

1986-88

Chisholm discovers **Prochlorococcus** in the Sargasso Sea.
It is the smallest and most abundant photosynthetic organism on the planet, responsible for **20% of the oxygen** released into the atmosphere each year.



10 000 cells mL^{-1}

a wine glass (250 ml) contains a number of these cells equal to the population of Paris

Images par Anne Thompson, Chisholm Lab, MIT
https://ocean.si.edu/milestones-marine-microbiology

What is the impact of the ocean fine scales on phytoplankton diversity?

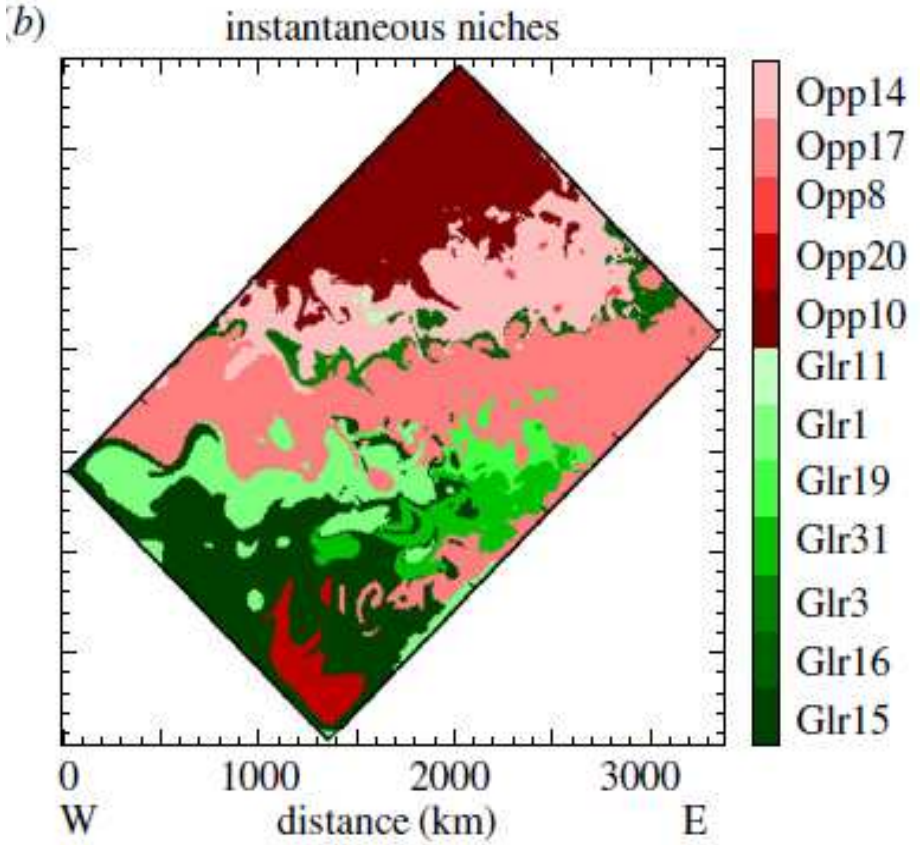
The ocean finescale (1-100 km, days to weeks)

Is very energetic (horizontal and vertical)

Has the same temporal variability of microbial demography

Has a well recognized impact on bulk production

Models predict its impact on phytoplankton diversity



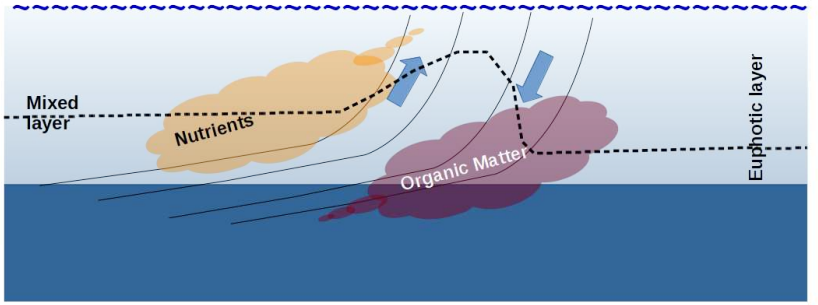
DARWIN model

[Lévy et al. 2015]

Fine-scale biophysical key processes

- impacts the carbon pump →

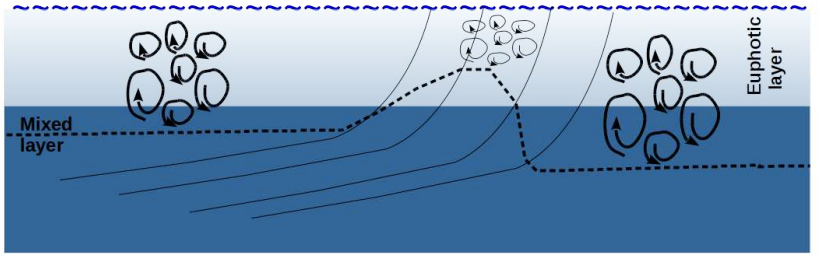
advecting nutrients upward and organic matter downward



[based on Lévy et al., 2012]

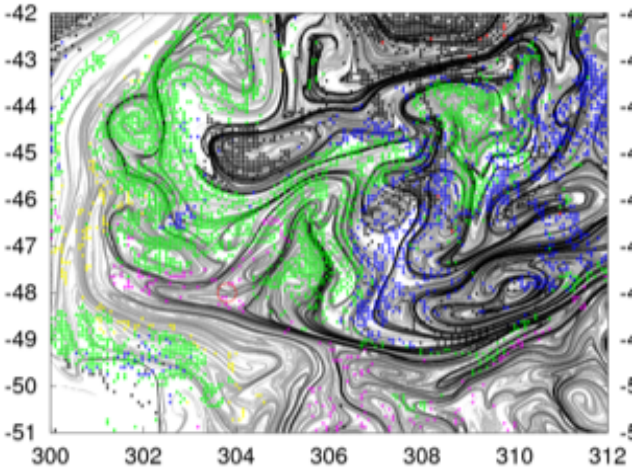
- controls the mixing →

influencing primary production, grazing and predation



- drives the biodiversity →

creating "fluid-dynamical niches"



Satellite data (FSLE & Physat)

[from d'Ovidio et al., 2010]

Fine scale biophysical key processes

- impact

adve

and

- con

influe

grazi

- drives the biodiversity →

creating “fluid-dynamical niches”

Modellers generally highlight the need of in situ measurements at submesoscale :

a big challenge due to the ephemeral character of these structures

A possible solution :

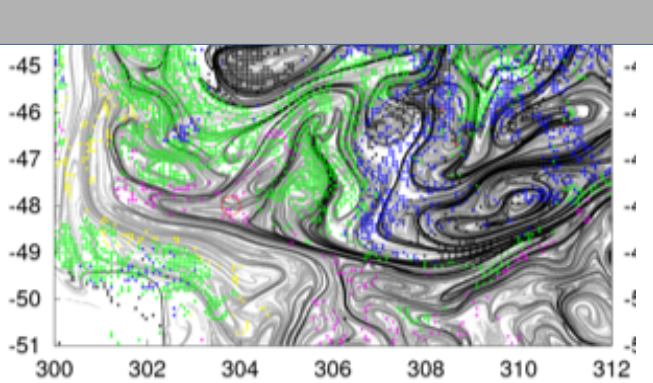
Adaptive Lagrangian sampling strategies

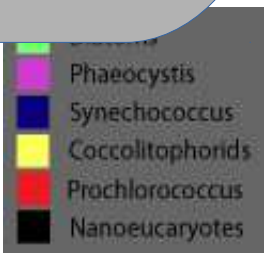
&

Innovative multidisciplinary instrumentation

d on
et al.,

at)





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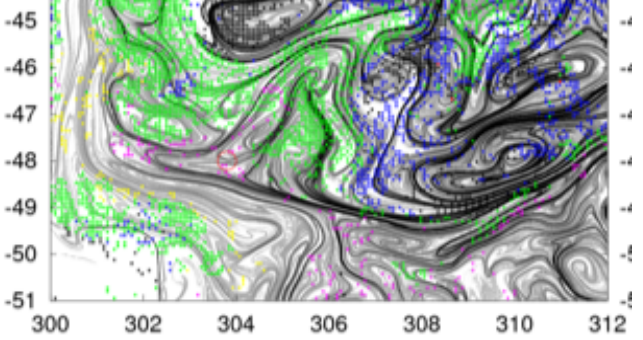
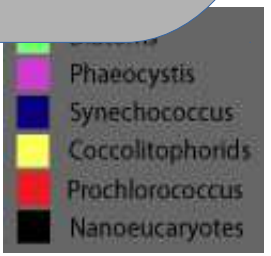




[from d'Ovidio et al., 2010]

Adaptive sampling strategy

(Target the structures!)

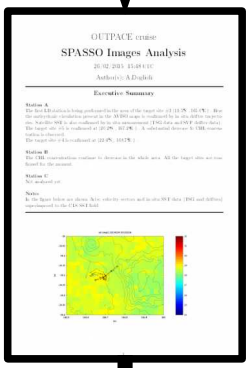
Remote sensed measurements

(& Numerical ModelingForecast)

Land Server (retrieval + processing)

Data and Figures

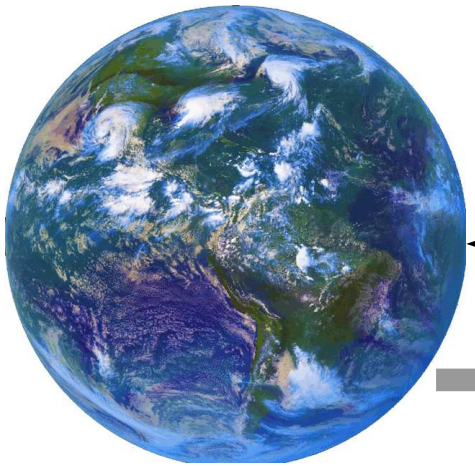
Daily Bulletin



SPASSO

***S**oftware **P**ackage for an **A**daptive **S**atellite-based **S**ampling for **O**cean campaigns*

https://spasso.mio.osupytheas.fr/



Sampling strategy

Preliminary results of

in situ HF measurements

In-situ campaign

Adaptive sampling strategy

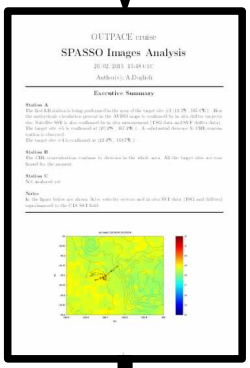
(Target the structures!)

Remote sensed measurements

(& Numerical Modelir

See the talk by
Louise Rousselet

Tomorrow morning



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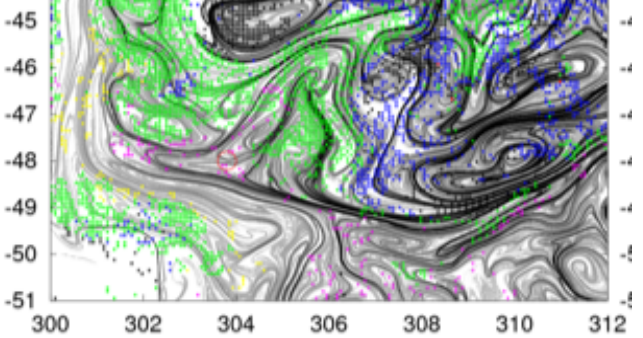
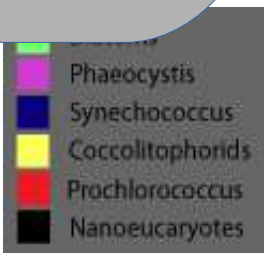




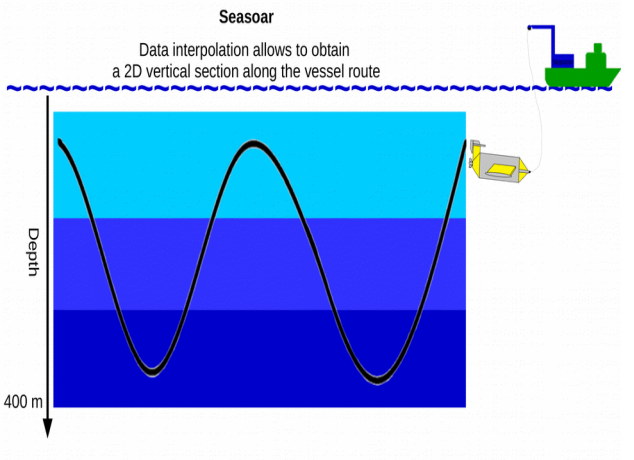
[from d'Ovidio et al., 2010]

Towed vehicles

Horizontal & Vertical Multidisciplinary Mapping

The SeaSoar

Multi-Sensor fish equipped with impeller-forced wings to undulate



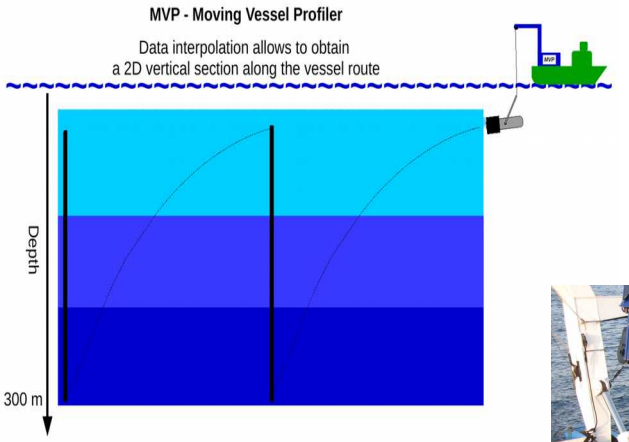
The MVP-**M**oving **V**essel **P**rofiler

A high-performance winch with Multi-Sensor **Free-Fall** Fish

CTD, fluorescence and LOPC

Laser Optical Particle Counter

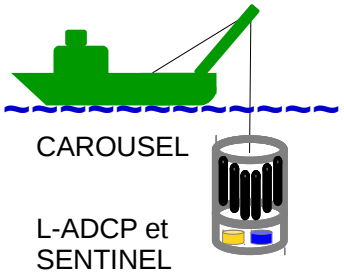
~2 km horizontal resolution
~1 m vertical resolution



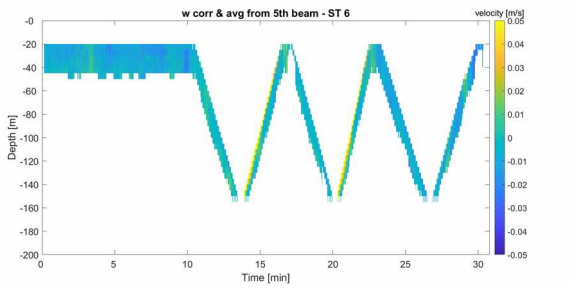
New methodologies to measure **W** in situ

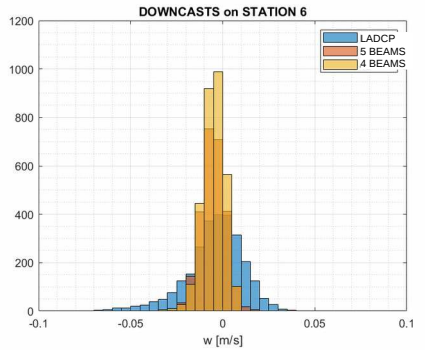
.

A 5-beams Sentinel ADCP and a L-ADCP deployed at fixed depth and yoyo

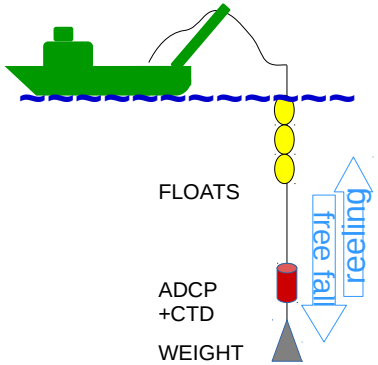


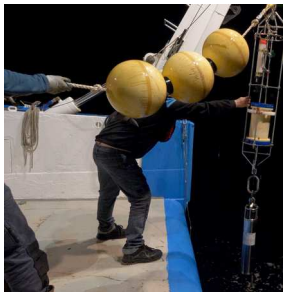
Correction with 1/ρg dp/dt



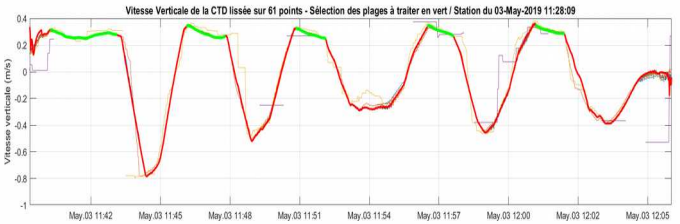


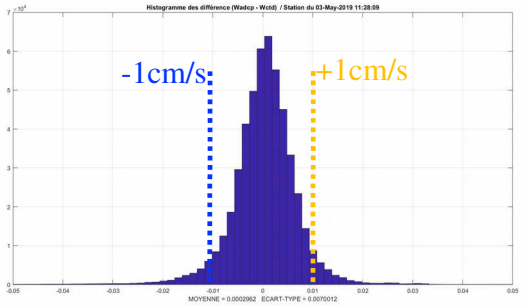
FF-ADCP (Free Fall ADCP)



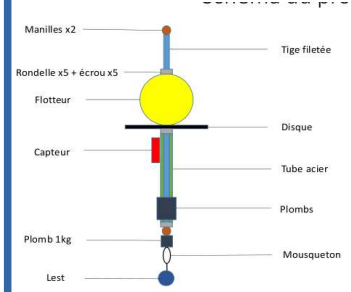


-- CTD --- ADCP





VVP (Vertical Velocity Profiler)



ANTENNA

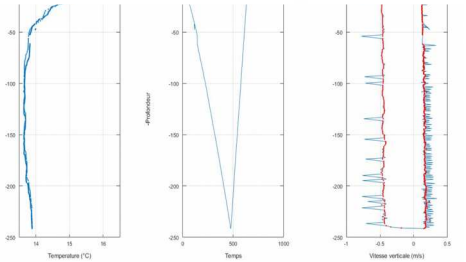
FLOAT

CTD
release
WEIGHT

Vertical acceleration =

Buoyancy – Gravity – Friction

Temperature Depth Velocity



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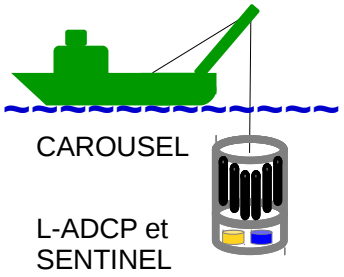

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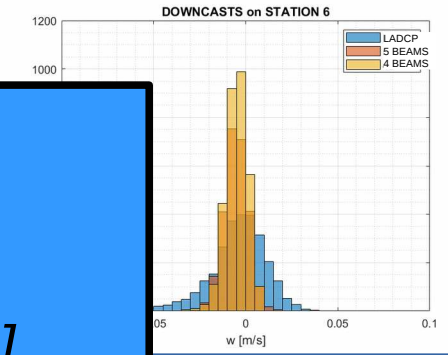
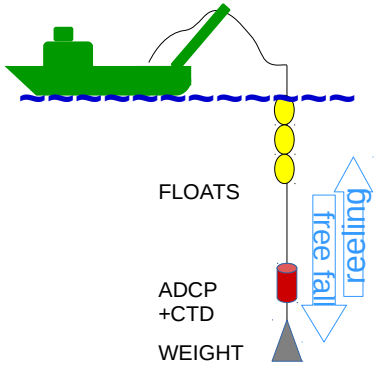
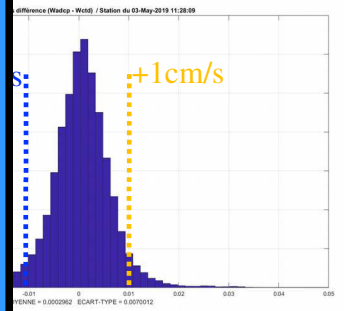


Campagne FUMSECK [Barrilon, 2019]

Comby et al., JAOT, 2022
https://doi.org/10.1175/JTECH-D-21-0180.1





VVP (Vertical Velocity Profiler)

ANTENNA

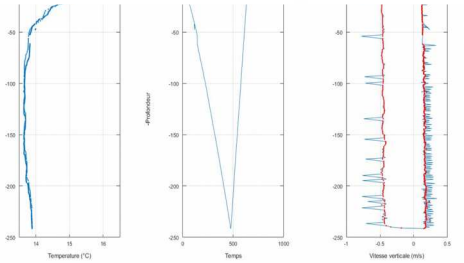
FLOAT

CTD
release
WEIGHT

Vertical acceleration =

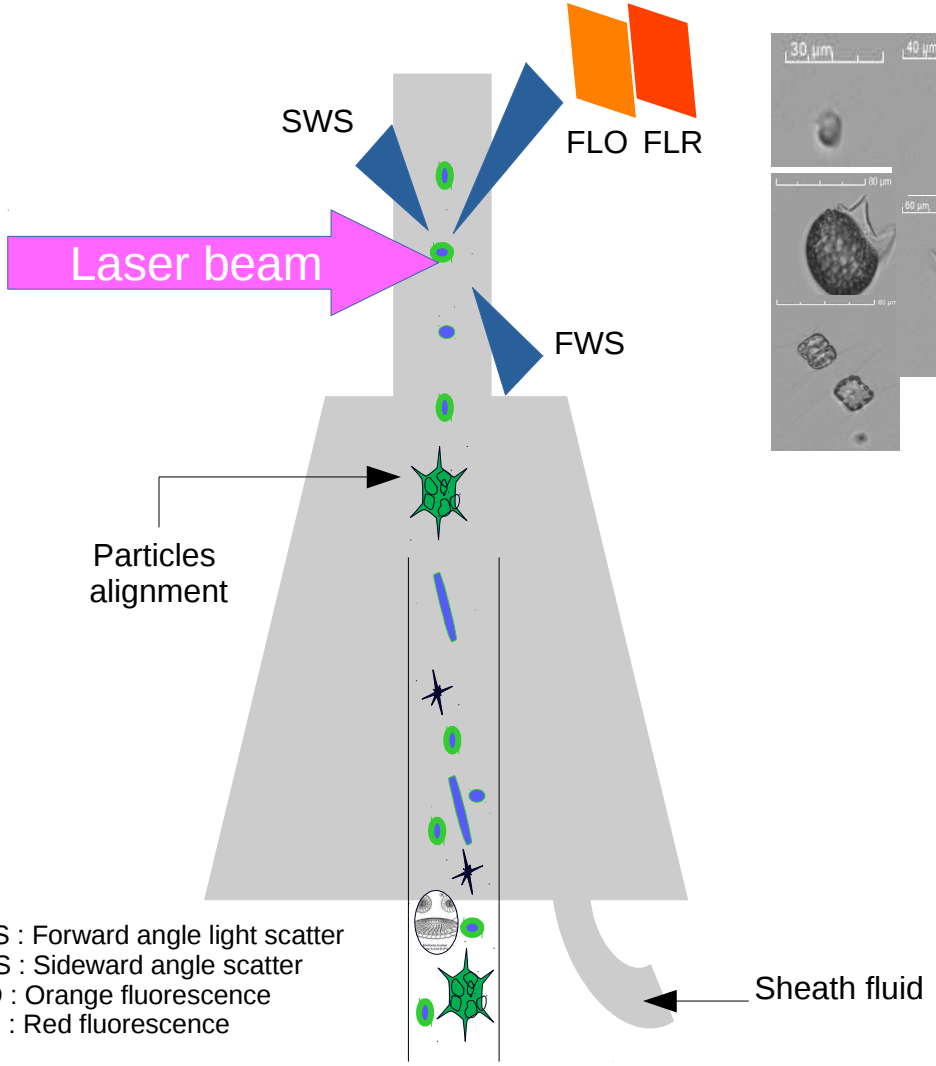
Buoyancy – Gravity – Friction

Temperature Depth Velocity

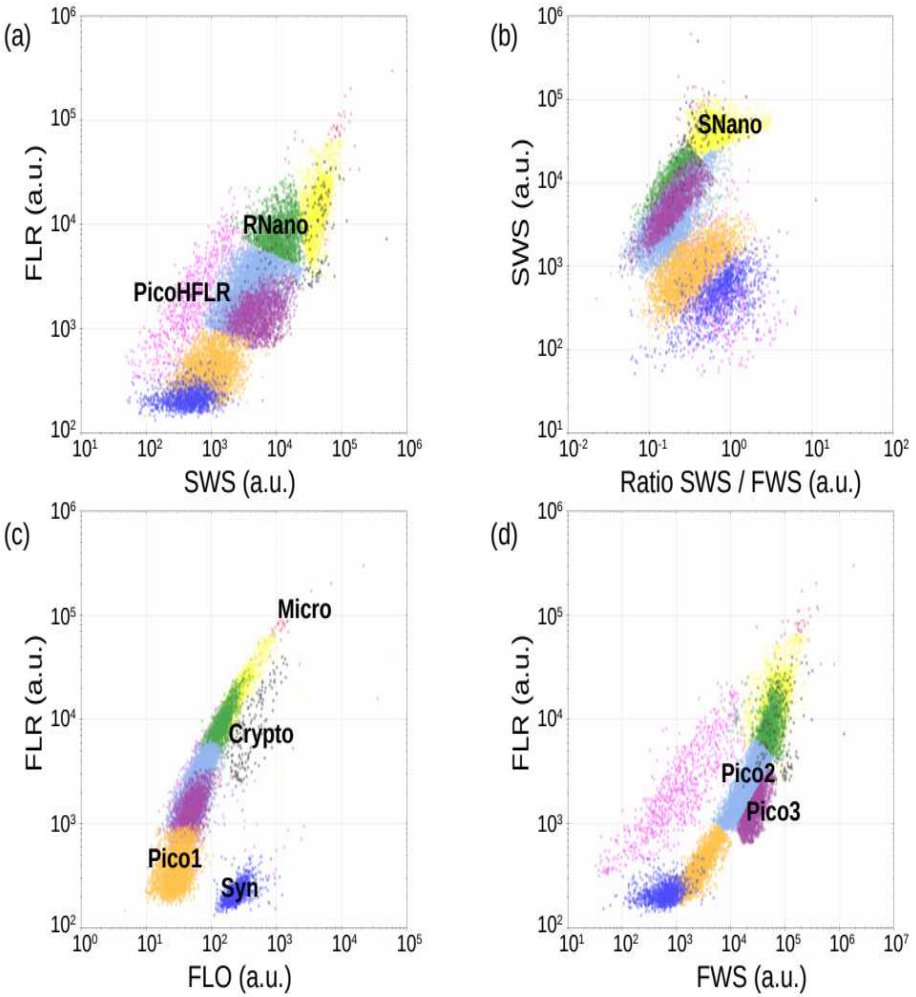


Flow Cytometry

On-board, near-real-time identification of phytoplankton groups



FWS : Forward angle light scatter
SWS : Sideward angle scatter
FLO : Orange fluorescence
FLR : Red fluorescence

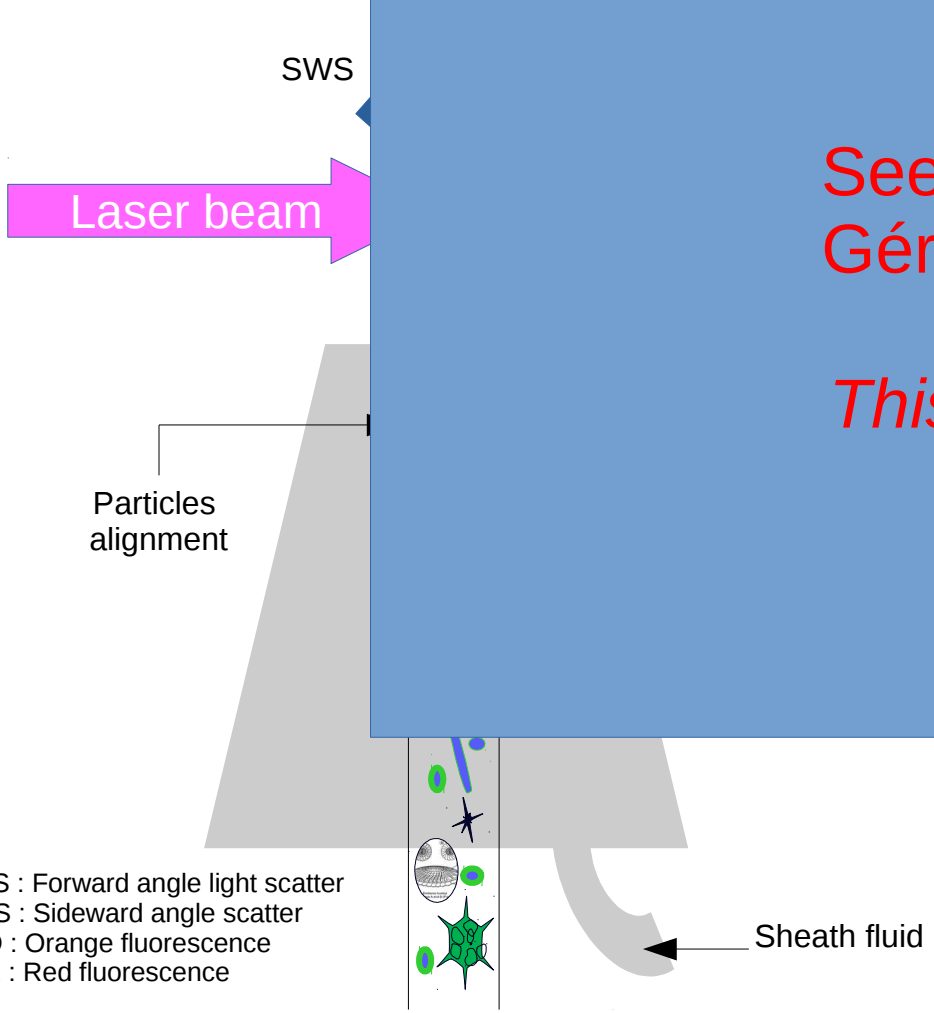


Flow Cytometry

On-board, near-real-time identification of phytoplankton groups

See the talk by
Gérald Grégori

This afternoon



FWS : Forward angle light scatter
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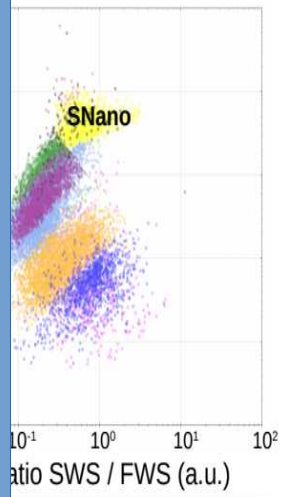
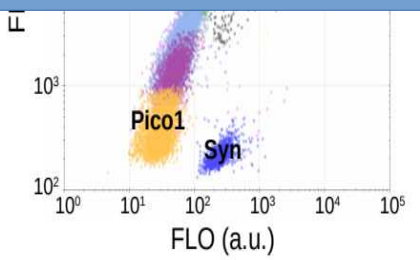
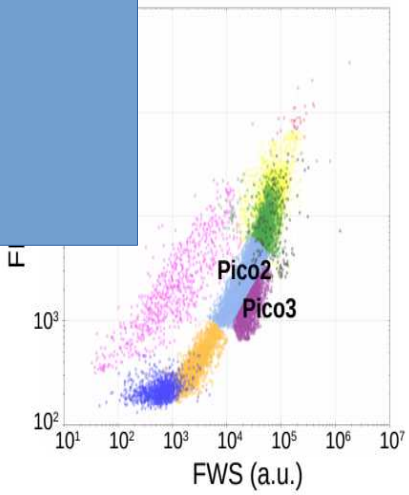
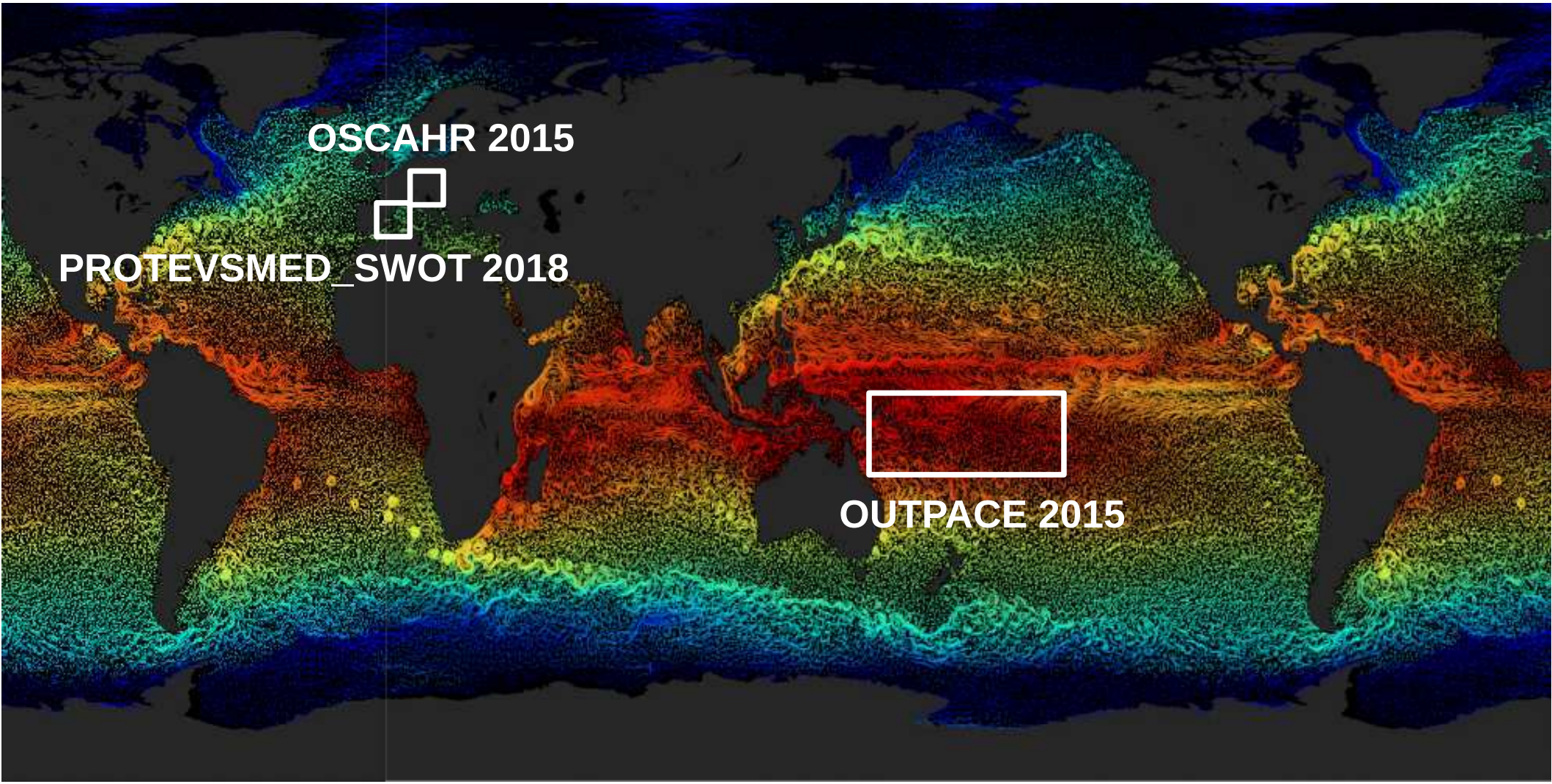






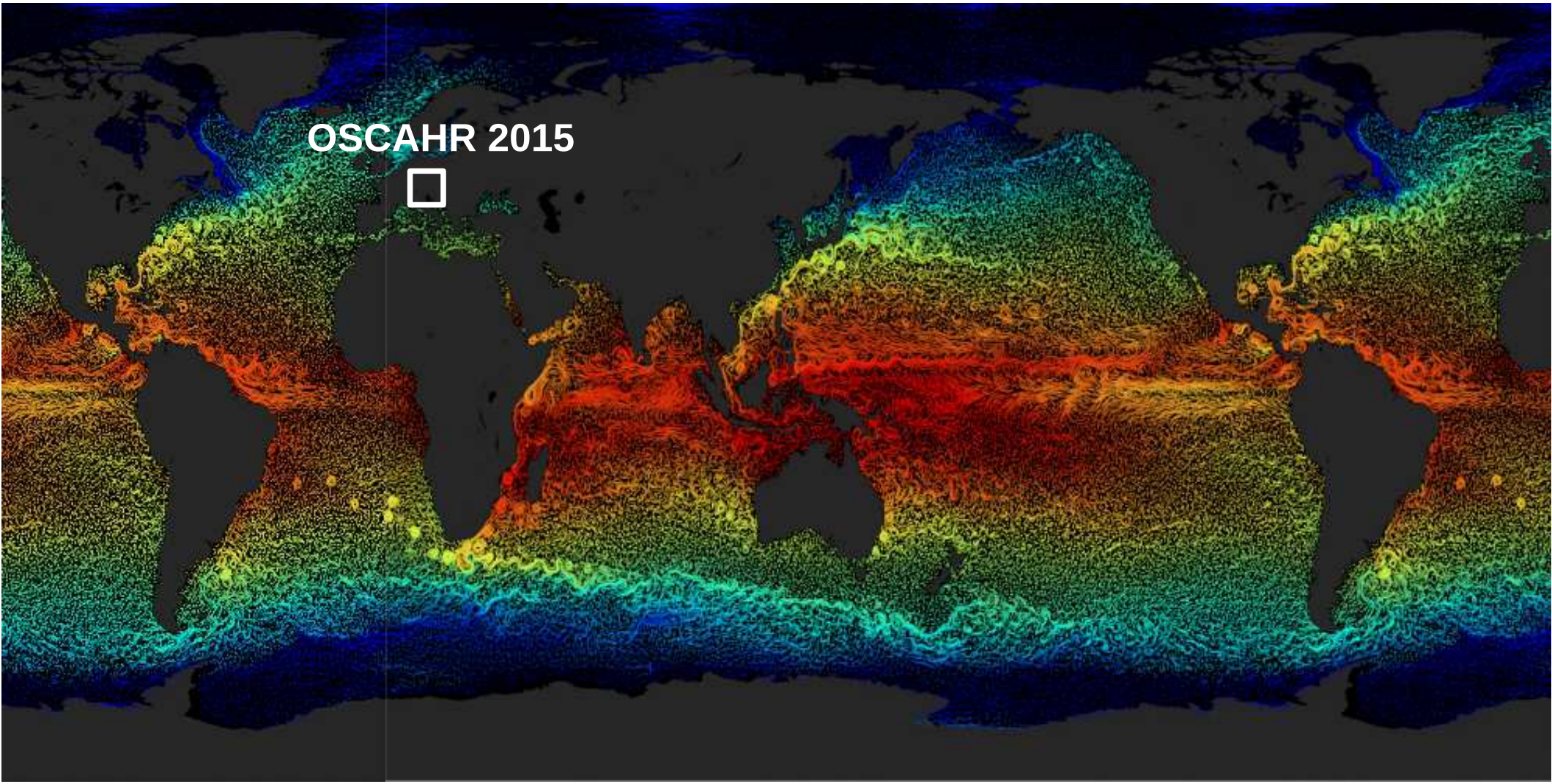
Exemples from three past cruises focused on the moderately-energetic and oligotrophic ocean



OSCAHR (nov ‘15)

Doglioli A.M., R/V Téthys II,

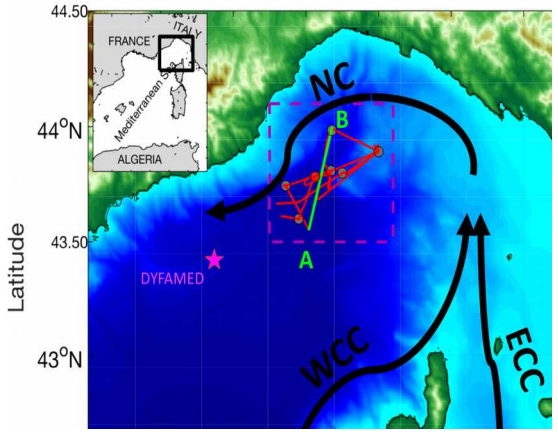
https://doi.org/10.17600/15008800

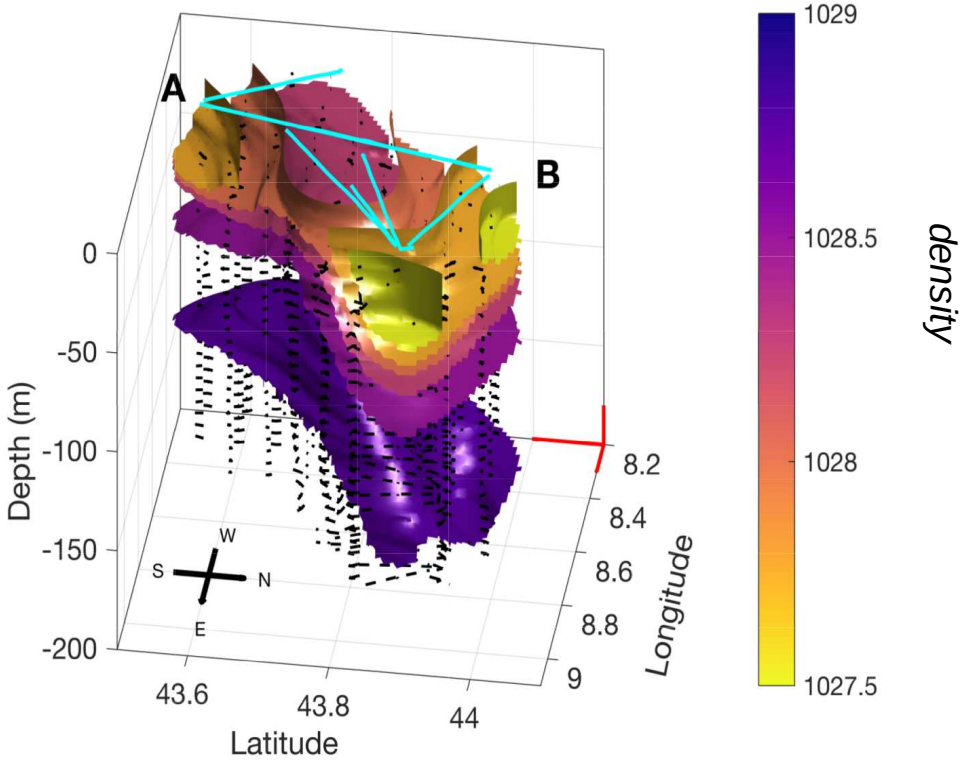


vertical motions and effects on biology

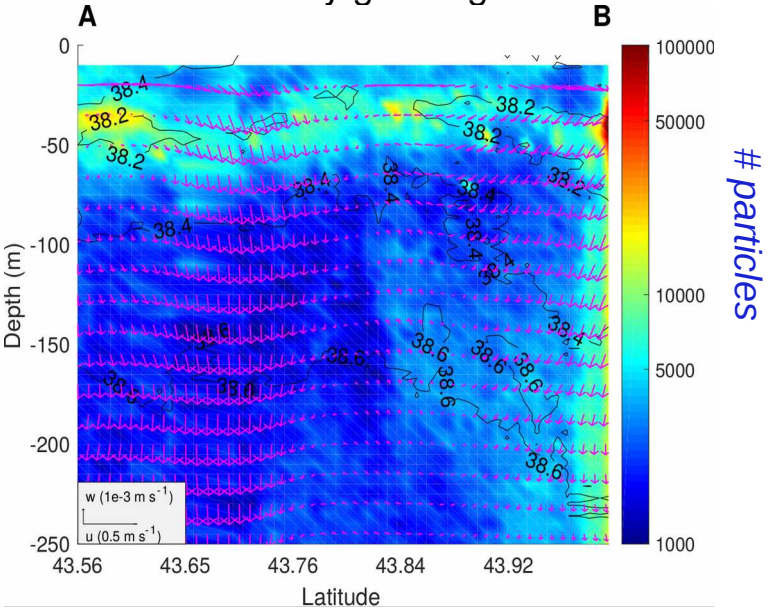
MVP and ADCP data :

reconstruction of 3-D fields of density
and horizontal and vertical velocities





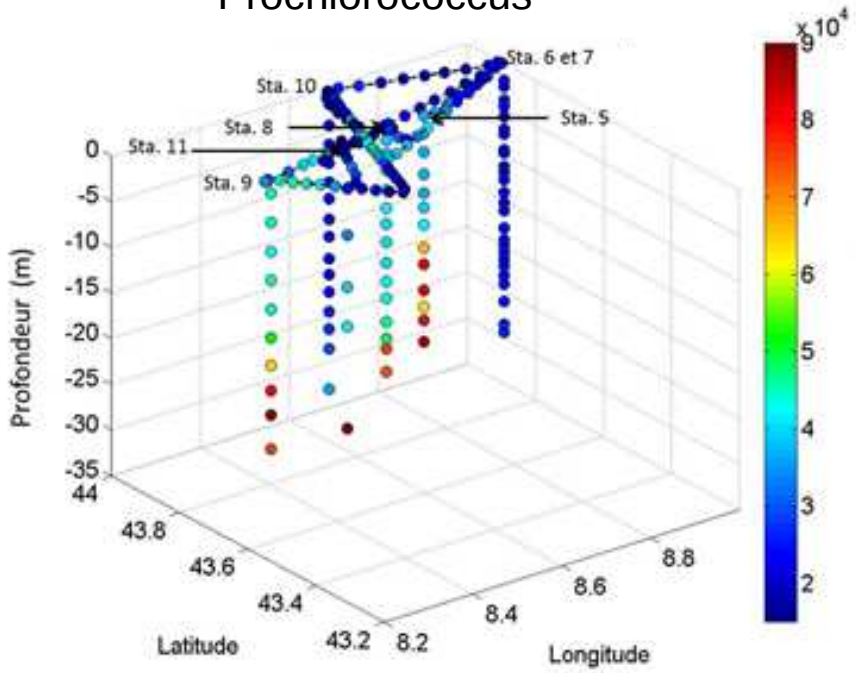
Combining w field with independent measurement of particles abundances measured with LOPC
we found a very good agreement!



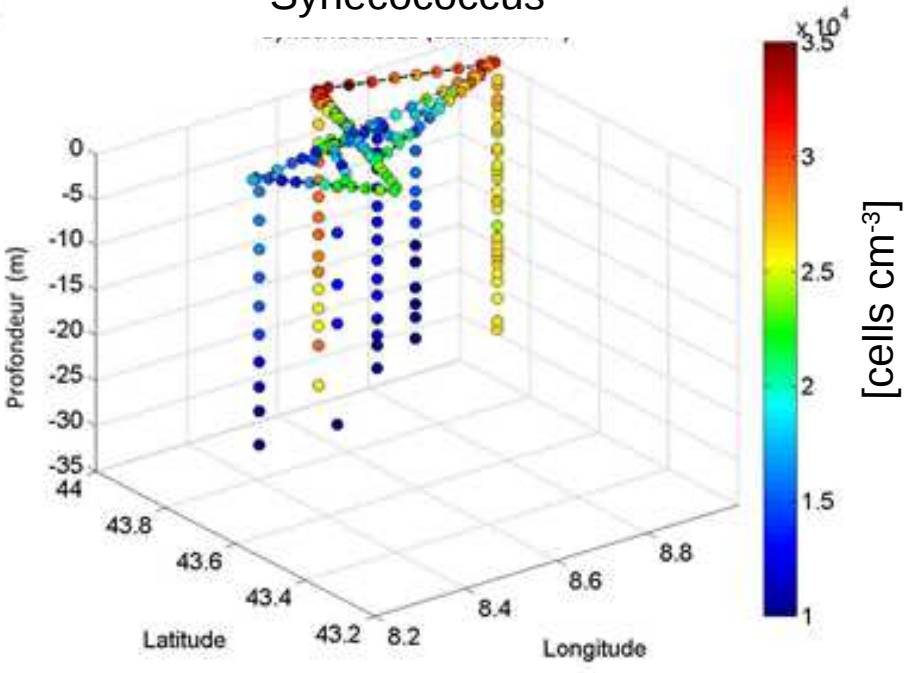
[Rousselet et al., 2019]

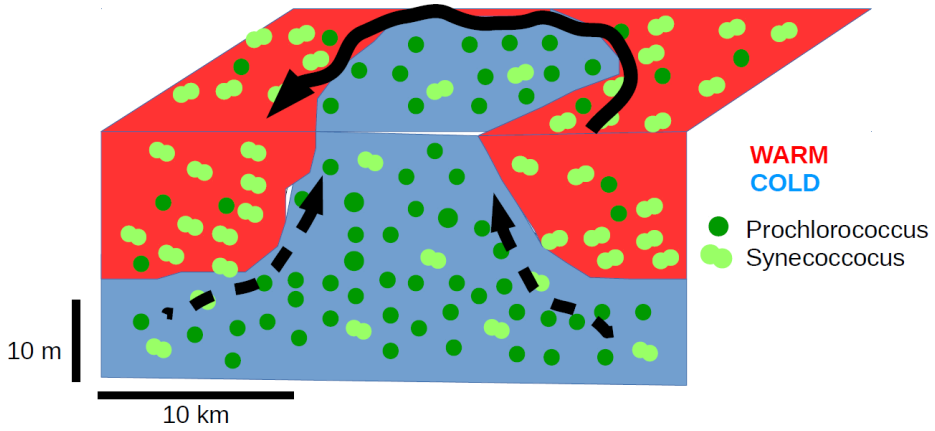
3D Phytoplankton assemblages from cytometry

Prochlorococcus



Synecococcus





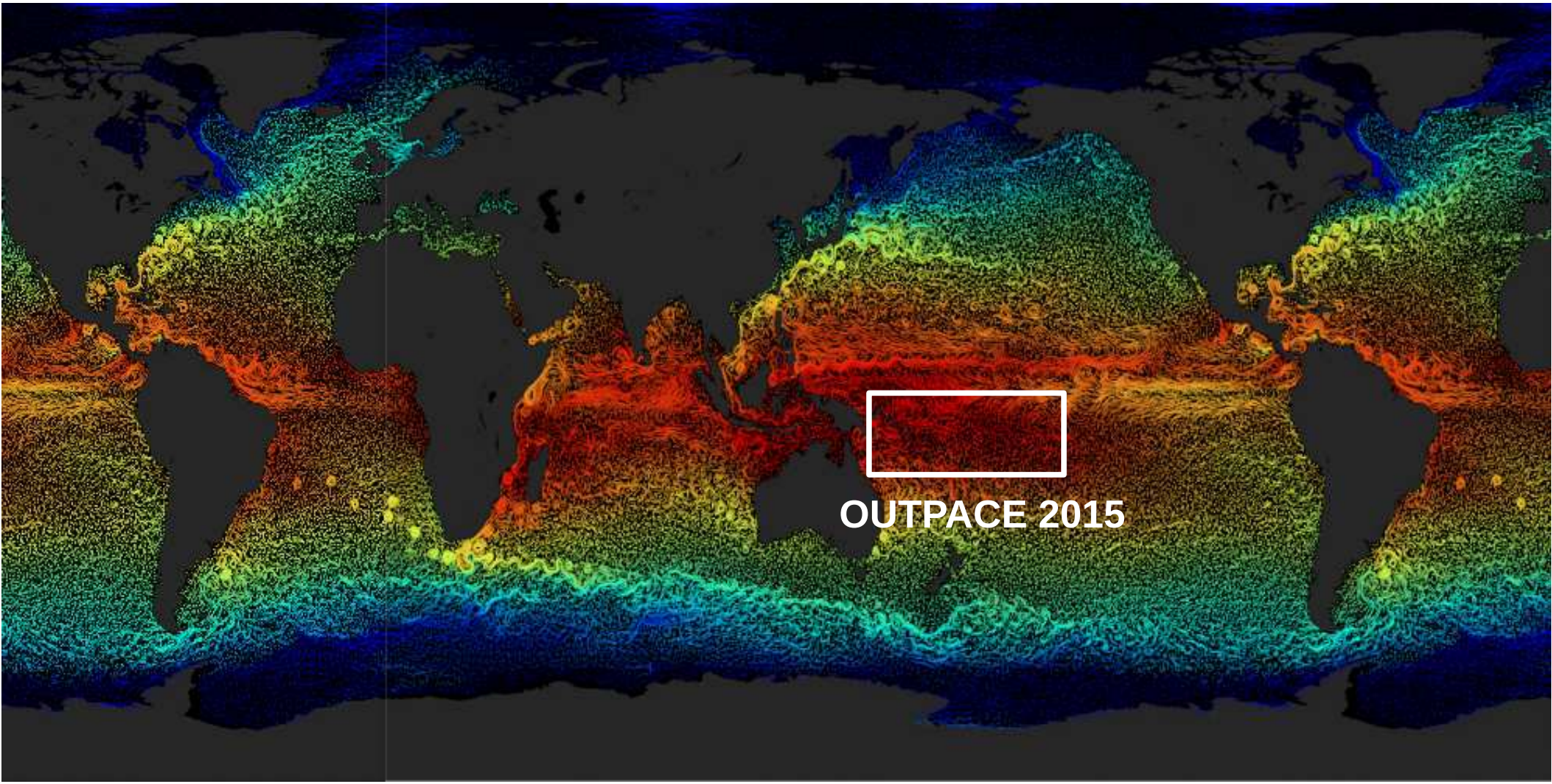
The fine-scale structure of the physical field as a driver for the spatial organisation of the planktonic communities

[Marrec et al., 2018]

OUTPACE (feb-mar ‘15)

MOUTIN Thierry, BONNET Sophie (2015), RV L'Atalante,

https://doi.org/10.17600/15000900



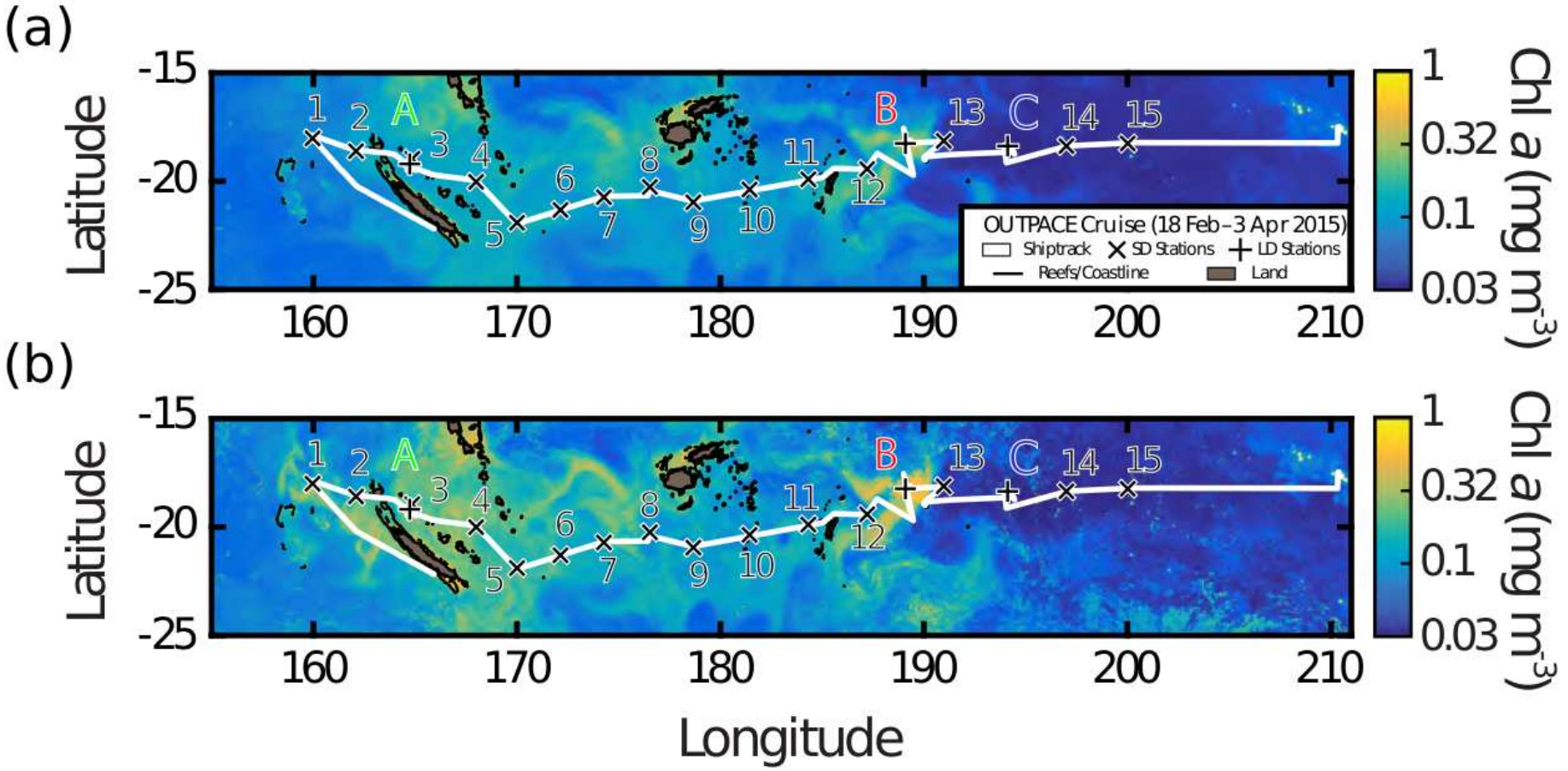
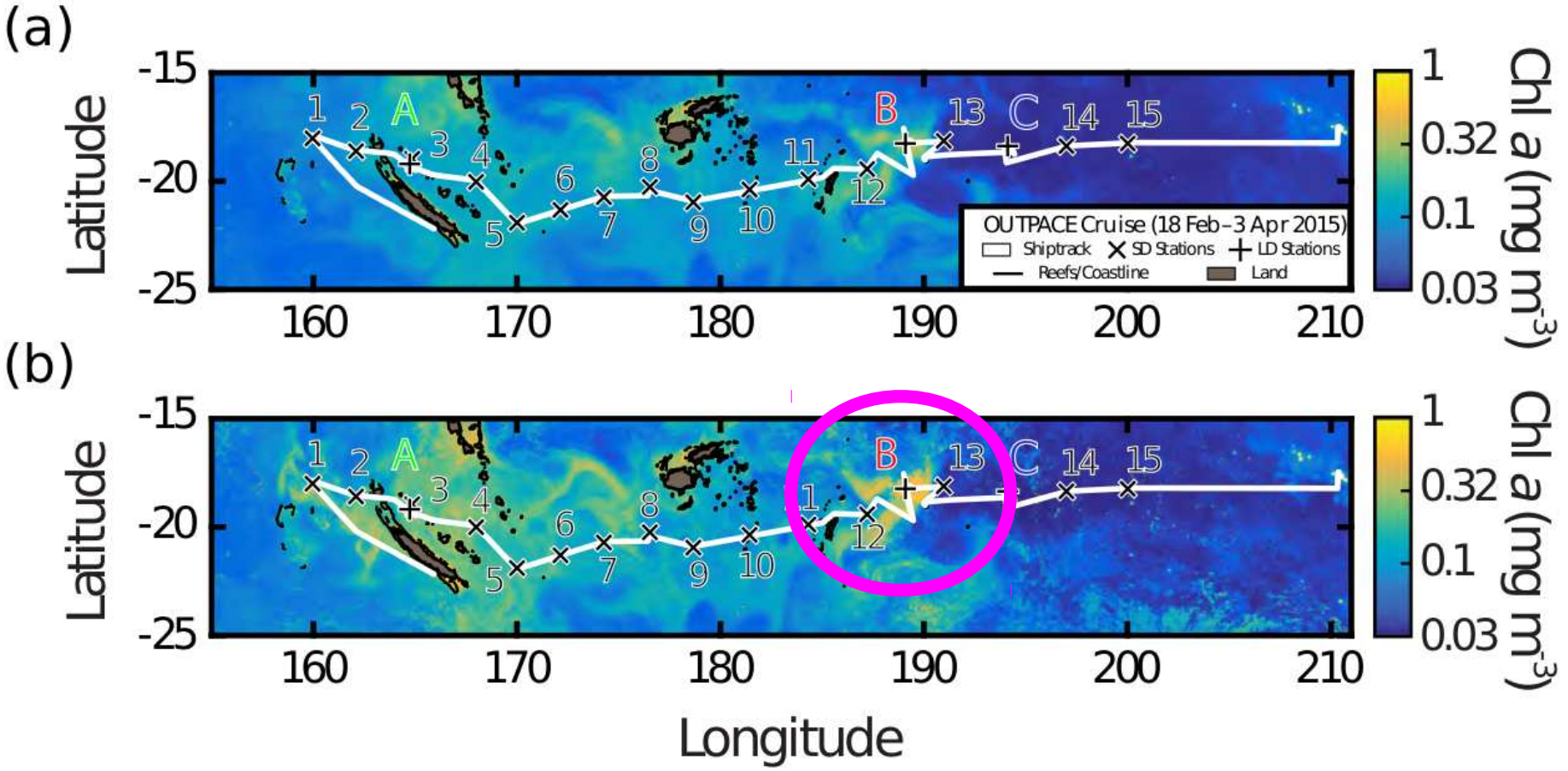


Figure 2. Transect of the OUTPACE cruise superimposed on **(a)** arithmetic mean surface chl *a* and **(b)** quasi-Lagrangian weighted mean chl *a* of the WTSP during OUTPACE. The two types of station, short duration (X) and long (+) duration, investigated for a period longer than 7 days, are indicated. The satellite data are weighted in time by each pixel's distance from the ship's average daily position for the entire cruise. The white line shows the vessel route (data from the hull-mounted acoustic Doppler current profiler (ADCP) positioning system). Coral reefs and coastlines are shown in black, land is grey, and areas of no data are left white. The ocean color satellite products are produced by CLS with support from CNES.

[Moutin et al., 2017]



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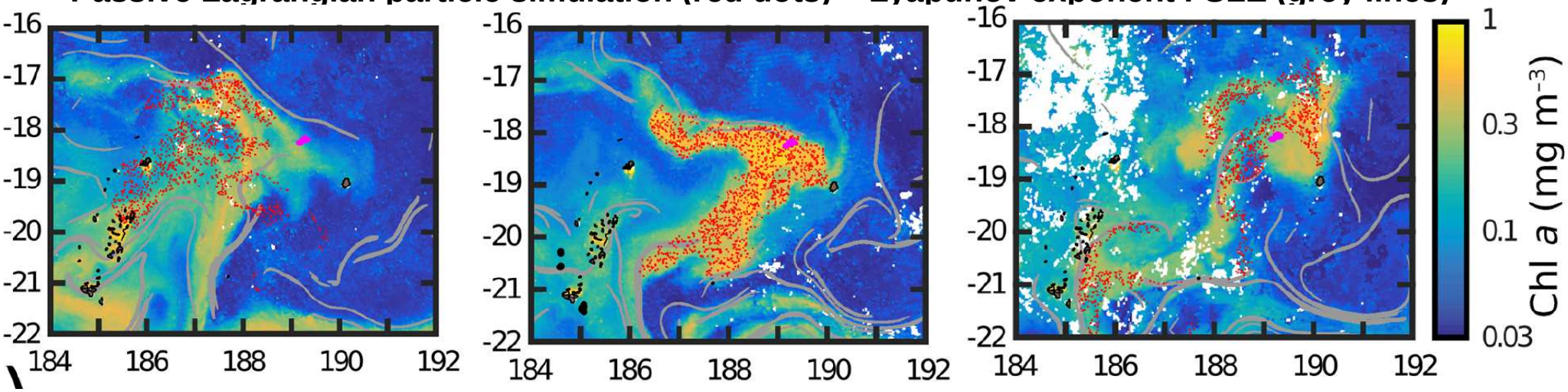
[Moutin et al., 2017]

Long-duration station LD-B

Biogeochemical data : bloom in oligotrophic waters
but…
MVP (physical) data : absence of submesoscale w, none vertical inection of nutrients
???

Passive Lagrangian particle simulation (red dots) + Lyapunov exponent FSLE (grey lines)



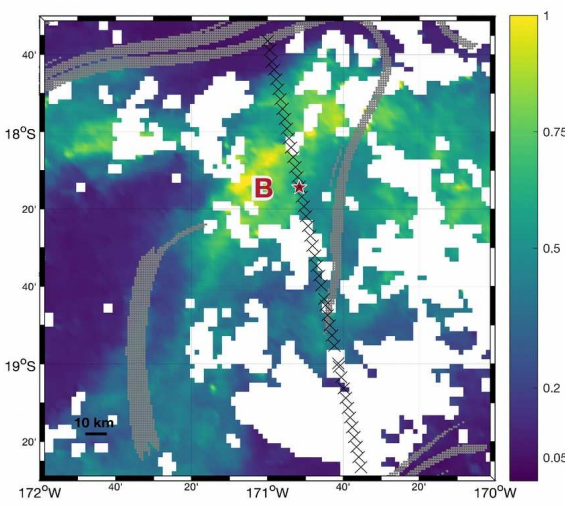
[de Verneil et al., 2017]

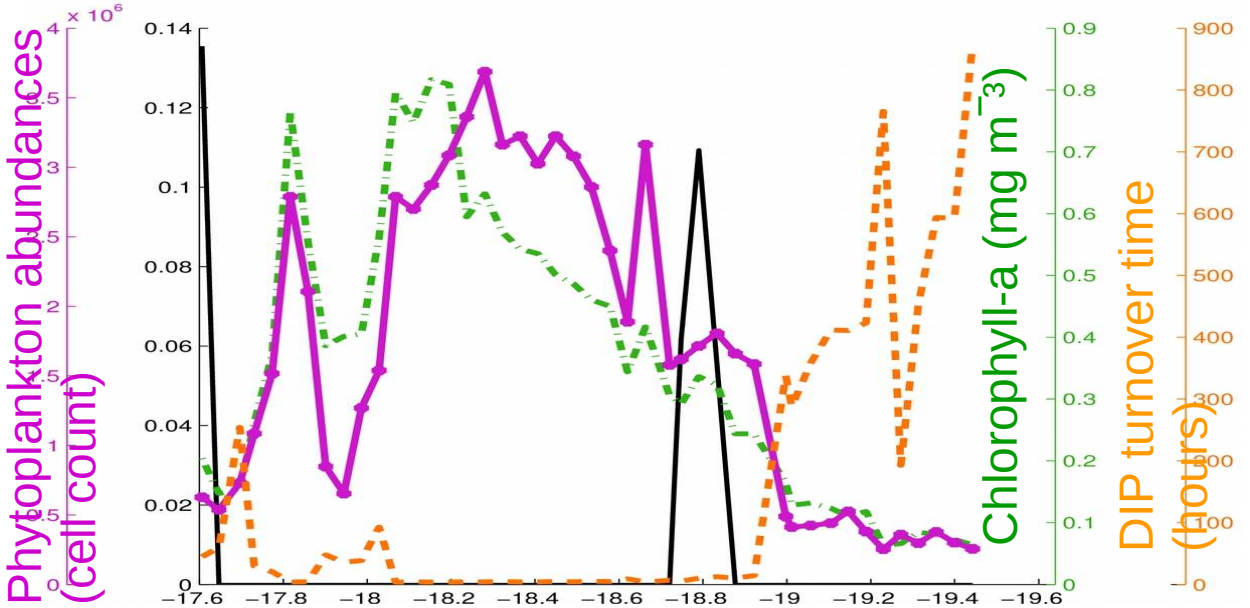
Answer obtained adding a simple plankton model :
Nitrogen fixers utilize phosphate and iron from islands while water masses get advected away by mesoscale circulation : the bloom is decoupled in time (several weeks) and space (hundreds of km) from island-driven nutrient supply.

The DIME : Delayed Island Mass Effect Messié et al [2020]

Transect LD-B to SD-13

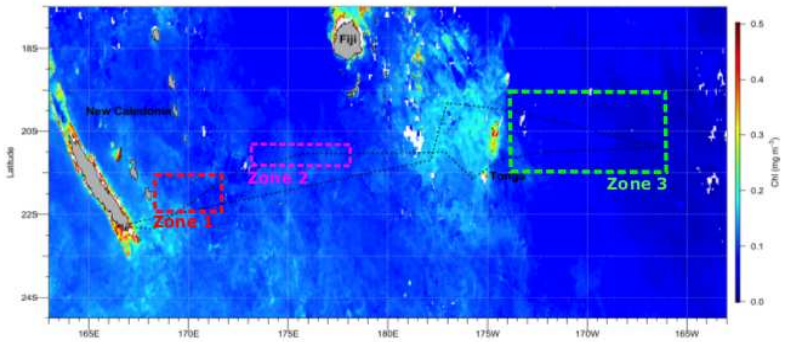
Barrier effect as identified by altimetry-derived FSLE observed in situ *[Rousselet et al., 2018]*

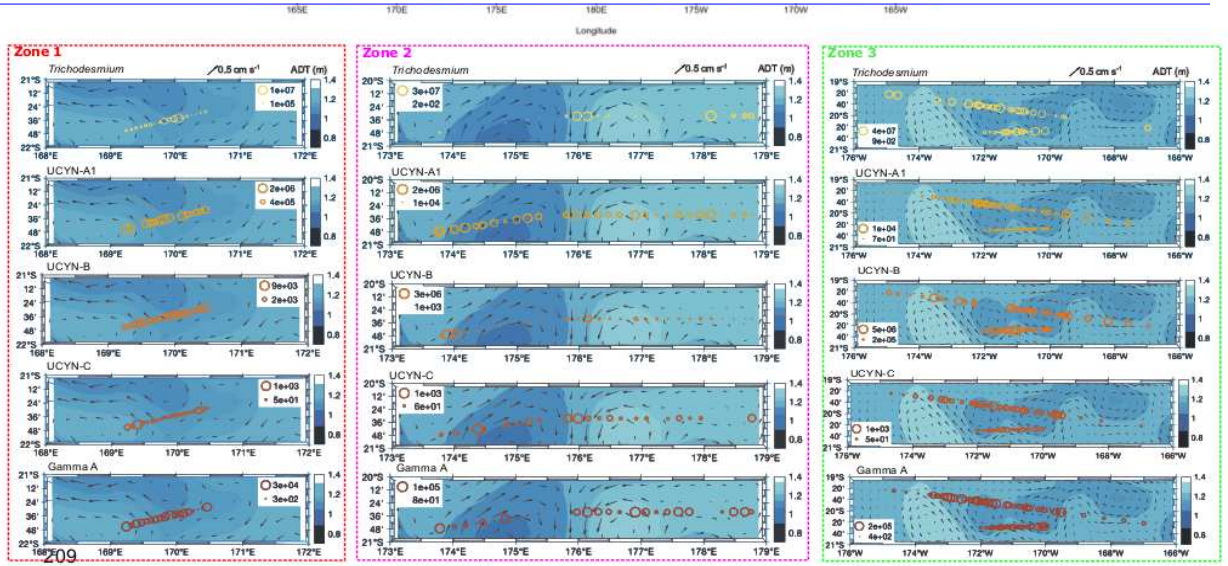




Confirmed by the successive
TONGA cruise (Guieu et Bonnet, 2019)

Benavides et al,o ISME Comm. 2021





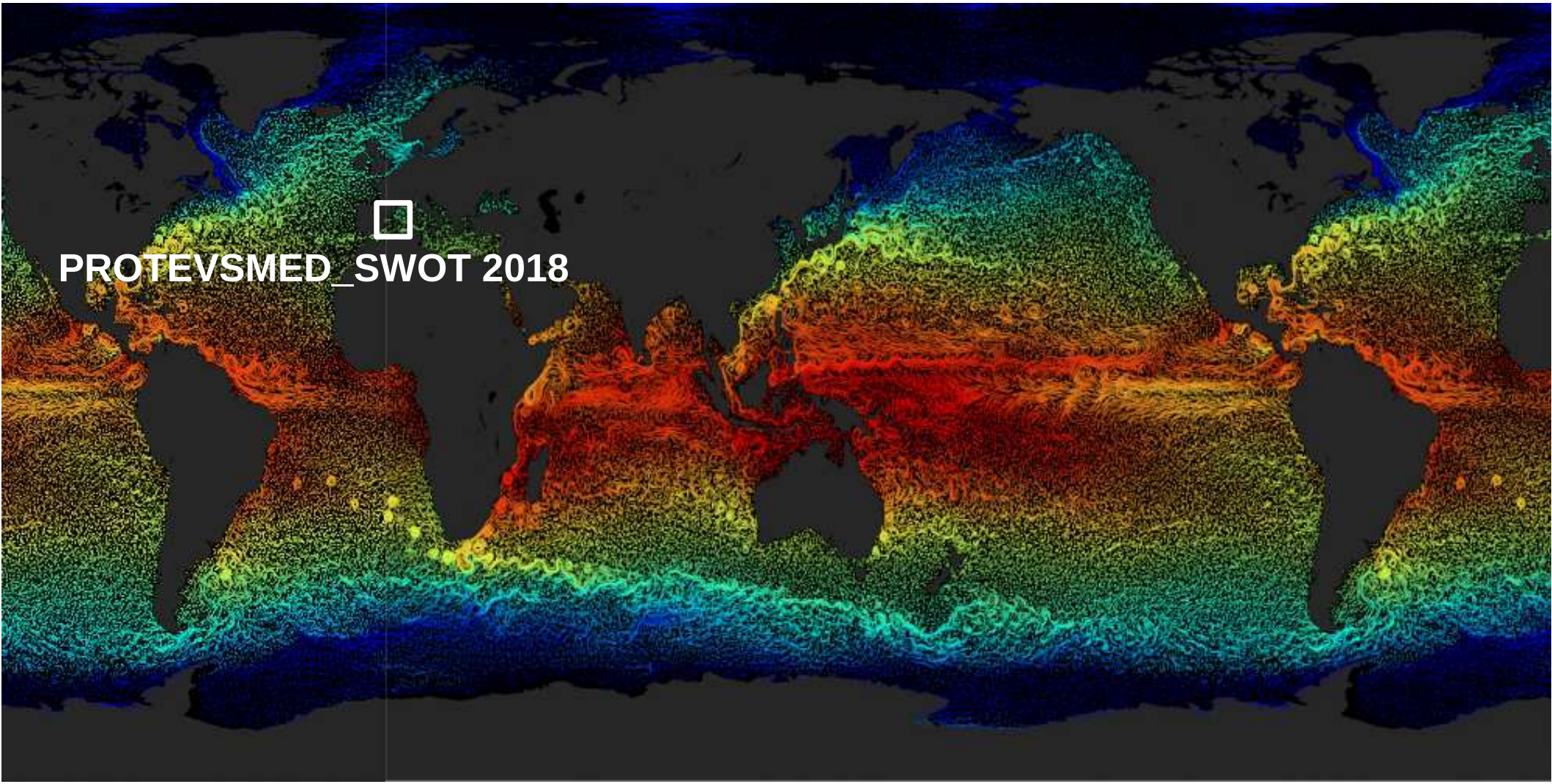
PROTEVSMED_SWOT (apr/may ‘18)

Dumas F., R/V Beautemps-Beaupré,

https://doi.org/10.17183/PROTEVSMED_SWOT_2018_LEG2

in synergy with ***PRE-SWOT***

Pascual A., R/V García del Cid



Onboard of the RV Beautemps-Beaupré

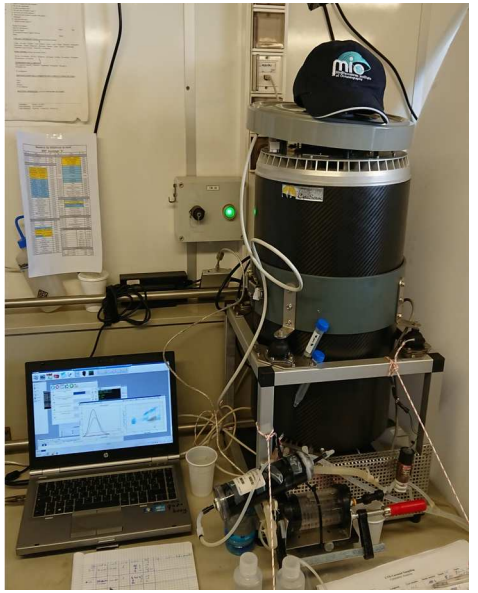
ADCP 150 & 38 kHz, TSG, SeaSoar (SHOM)
~3 km resolution & 300 m depth

Automated Flow Cytometer (MIO)

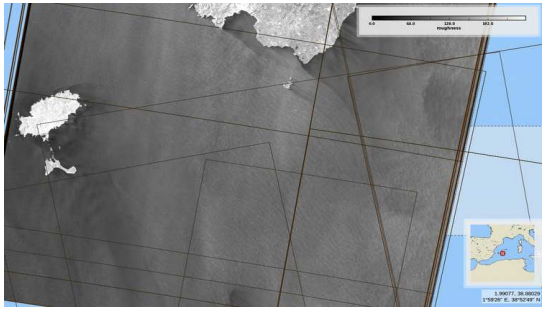
Identification of microbes from size, color, and shape.

One point every 20’

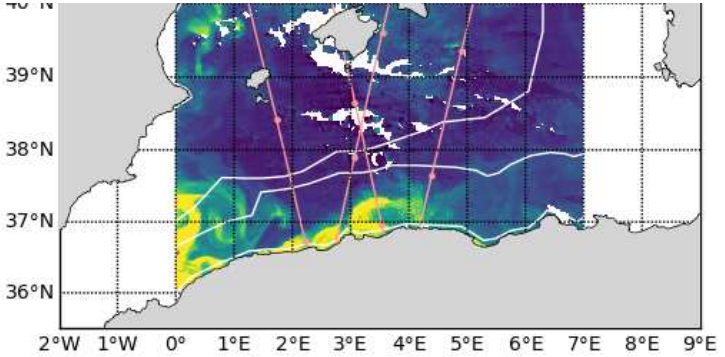
~= 5.5 km (@ 9 Knots)

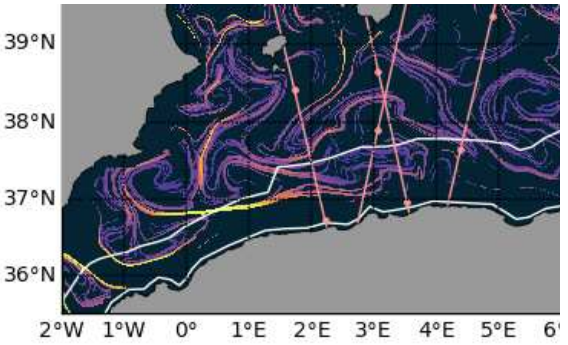


On land : multisatellite support



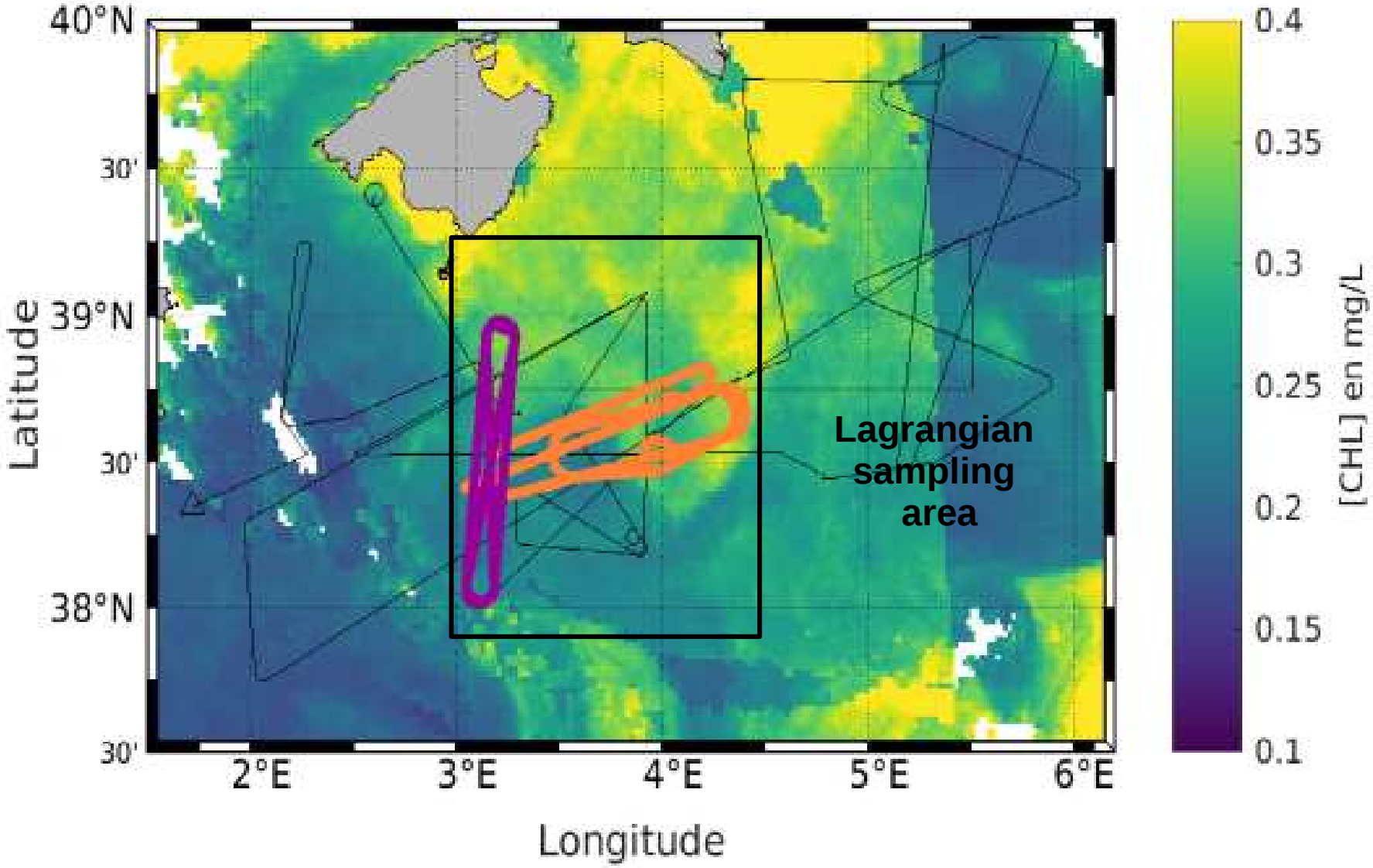
SAR





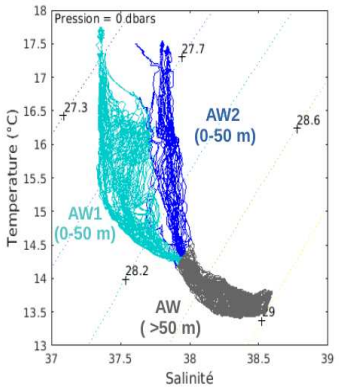
CLS data of SST and SCHL + Altimetry derived Lagrangian analyses by SPASSO http://spasso.mio.univ-amu.fr

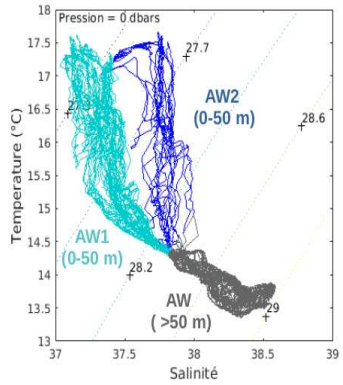
Sampling route



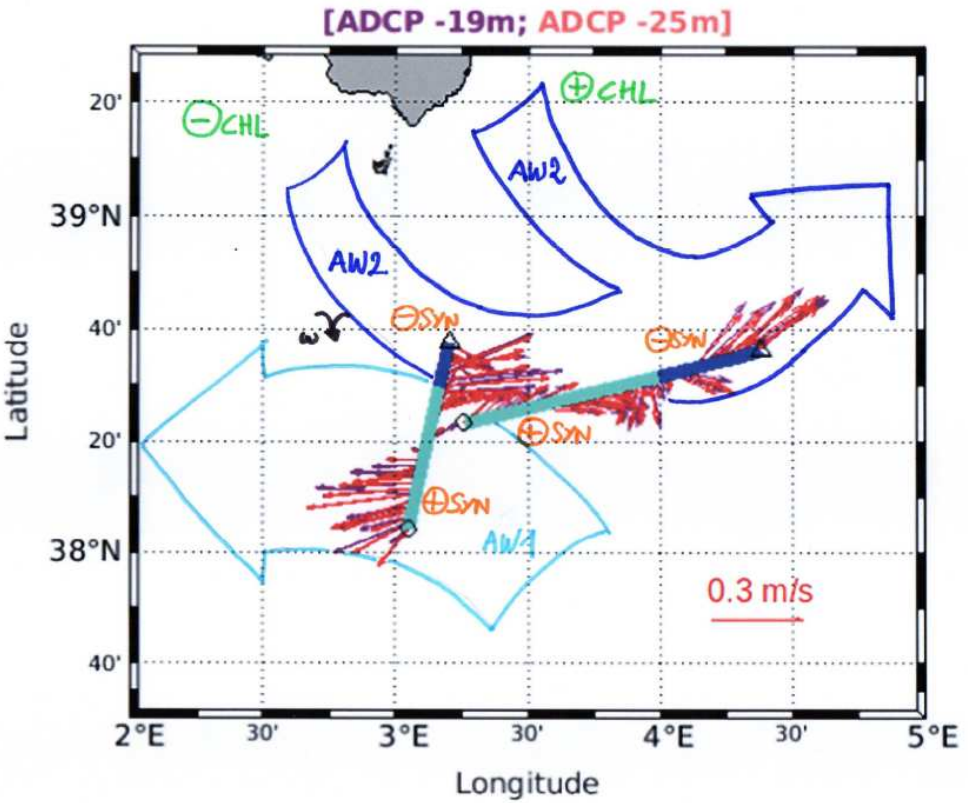
Results

HR hydrology

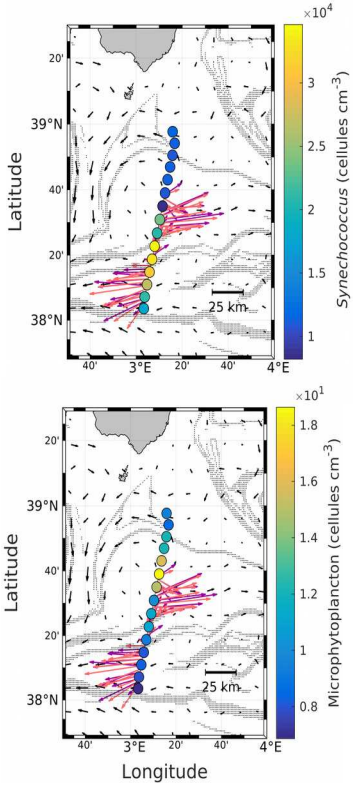




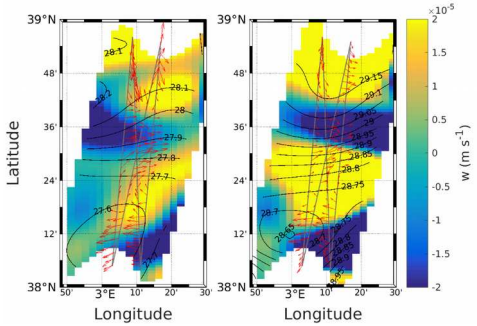
[Tzortzis et al, 2021, Biogeosciences]



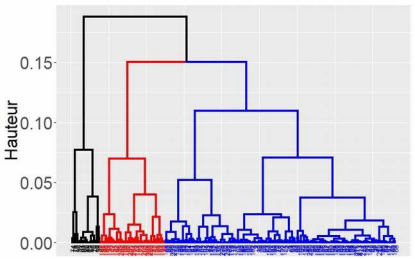
Phytoplankton Abundances

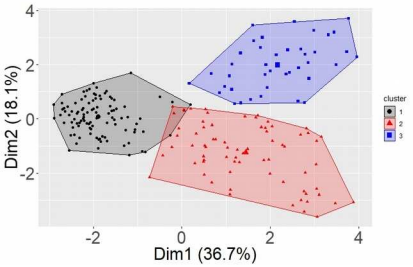


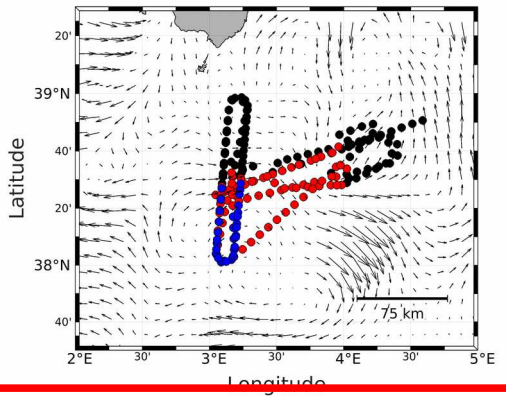
QG w estimation



Cluster analysis of phytoplankton groups







« back and forth » strategy for the horizontal continous sampling

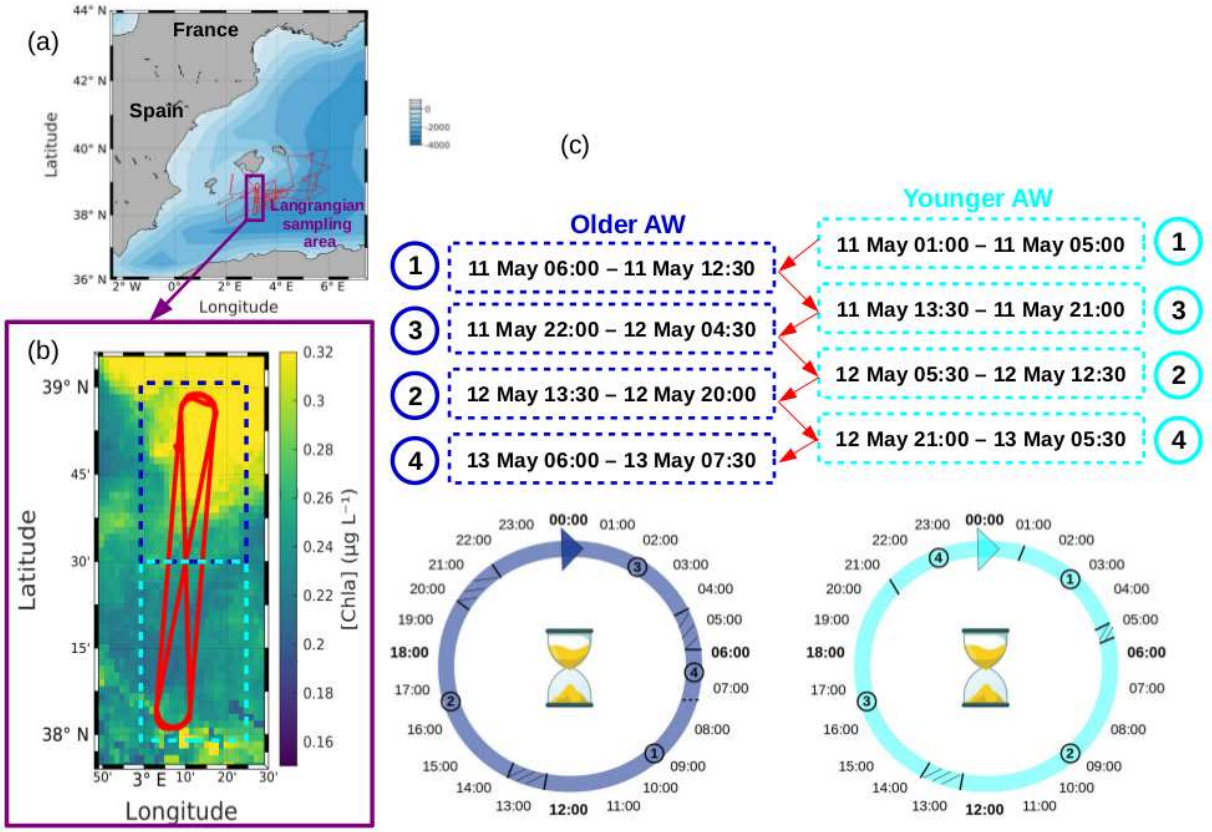


Figure 1. (a) Route of the RV *Beautemps-Beaupré* during the PROTEVSMED-SWOT cruise. The box in purple represents the area where we performed a Lagrangian strategy. (b) Map of [chla] of the 11 May 2018 superimposed on the route of the Lagrangian sampling across the older AW (in dark blue) and the younger AW (in light blue). (c) Dates of the transects across the older AW and the younger AW, used to reconstruct a day of 24 h period in each water mass.

Performing 8-hours transects, it is possible to cover the entire life cycle in 2 days

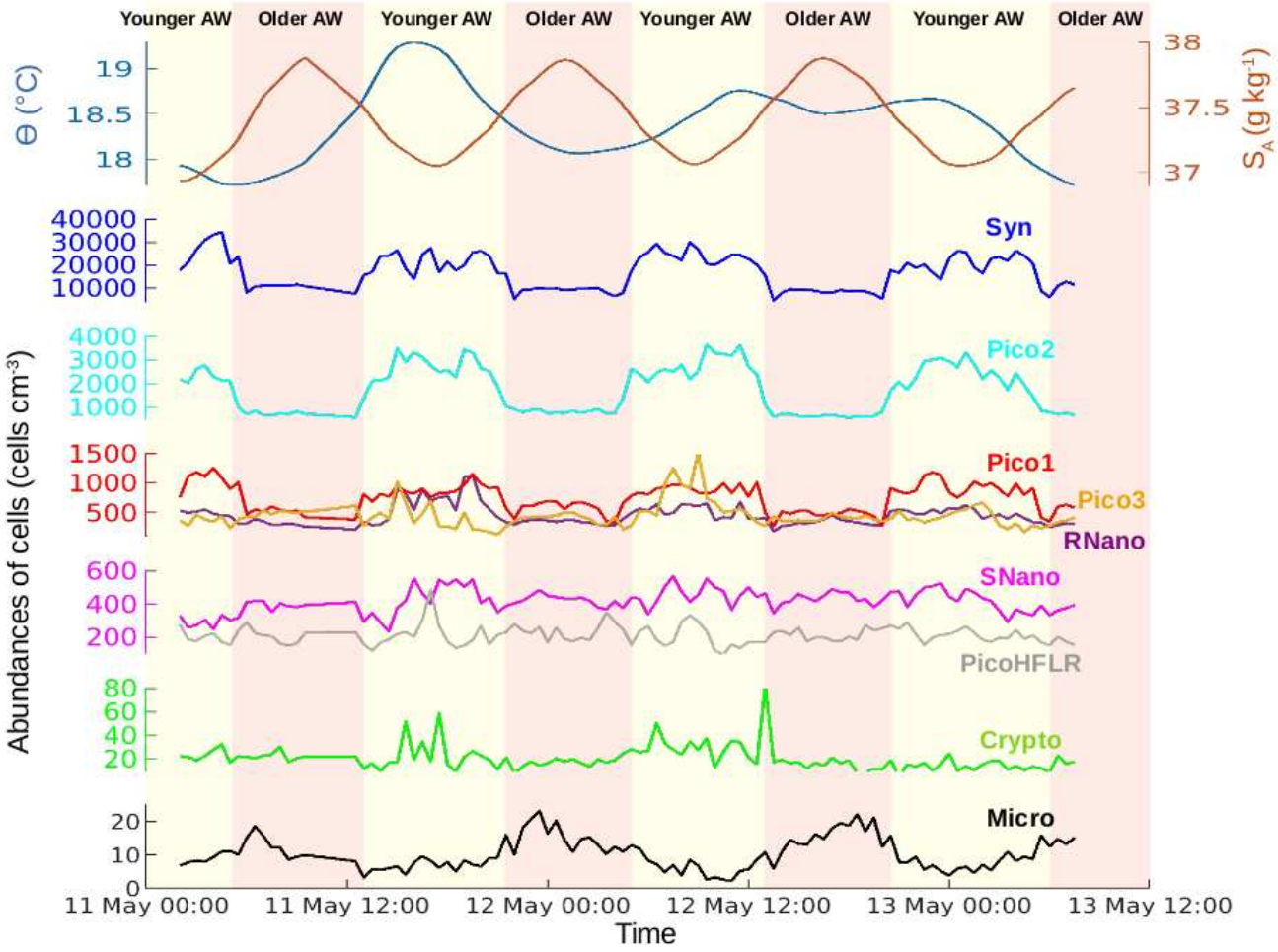
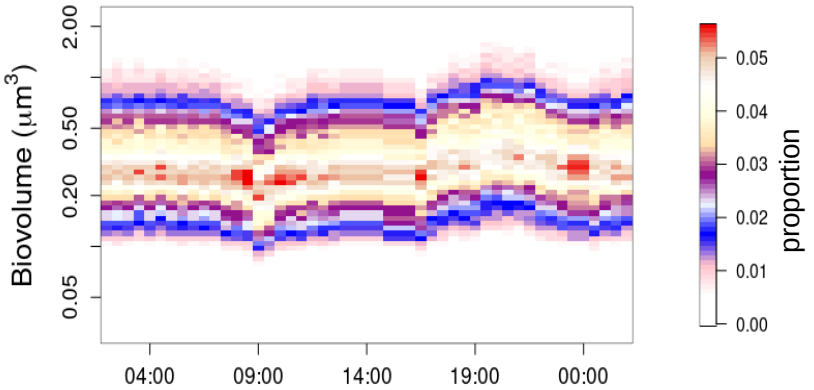


Figure 3. Temporal evolution of sea surface conservative temperature (Θ) in °C, absolute salinity (S_A) in $\mathrm{g\,kg^{-1}}$, and phytoplankton abundances in $\mathrm{cells\,cm^{-3}}$, from 11 May 00:00 to 13 May 12:00 (UTC). Vertical colors correspond to the two water masses separated by the front (see Fig. 1).

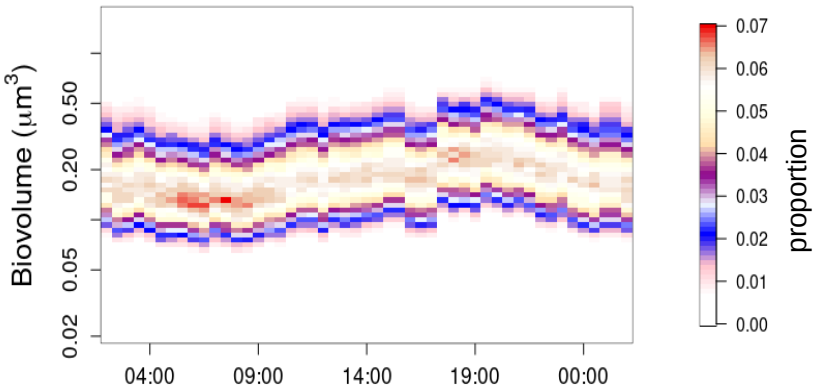
Conversion FWS into biovolume

Exemple : Synechococcus

Young AW



old AW



The size-structured population model (Sosik et al., 2003)

Cells transit in the different size classes upon a circadian clock regulating the cell cycle

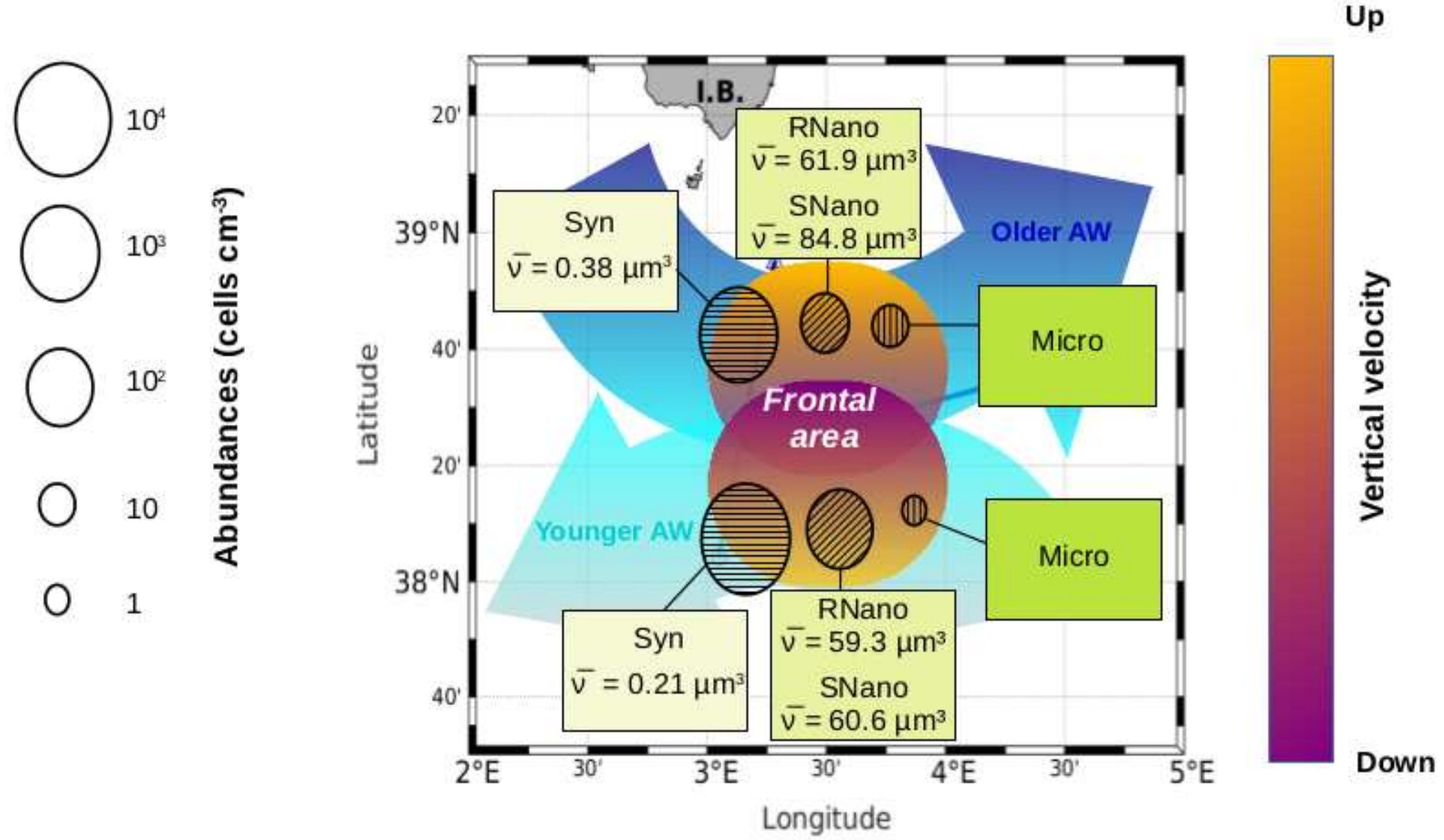
Growth rates by cytometry.

$$\mu_{size} = \frac{1}{t+dt} log_e \left(\frac{\hat{N}(t+dt)}{N(t)} \right)$$

→ µ : growth rates
→ N : number (proportion) of cells in size classes
→ t : time

[Tzortzis et al., to be submitted to Biogeosciences]

Phytoplankton growth rates in the frontal area



[Tzortzis et al., to be submitted to Biogeosciences]

Summary of previous campaigns

Satellite-based adaptive and Lagrangian strategies proved to be successful to target and follow fine-scale structures in situ.

When paired with *in situ* high-frequency biological measurements (e.g. automated cytometry) these strategies highlight the important role of the fine scales in structuring the phytoplankton community by acting as fluid dynamical barriers and biodiversity hot-spots.

Innovative methodologies are in development to directly measure in situ the vertical velocity and to increase the geochemical and biological sampling.

Outlook for the next campaign (2023)

To perform a cruise in the oligotrophic and moderately energetic SW Med :

i) sampling fine-scale dynamics,
ii) measuring nutrient concentrations at nanomolar-precision,
Iii) performing high-resolution cytometry,
iv) estimating accurately the zooplankton grazing.

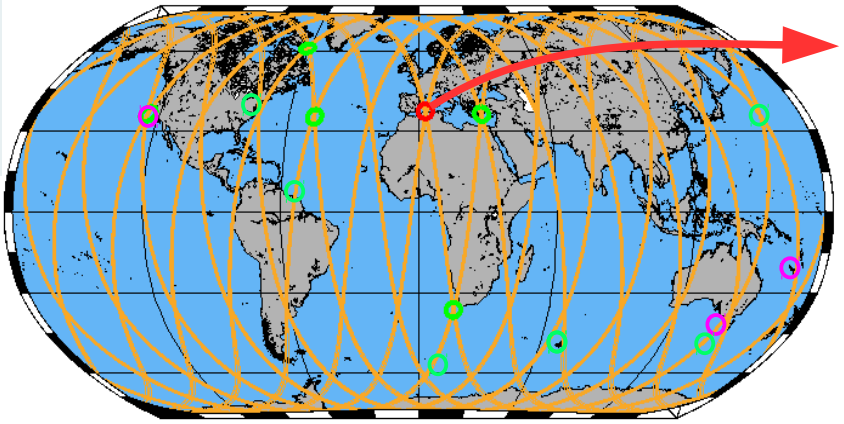
BIOSWOT-Med

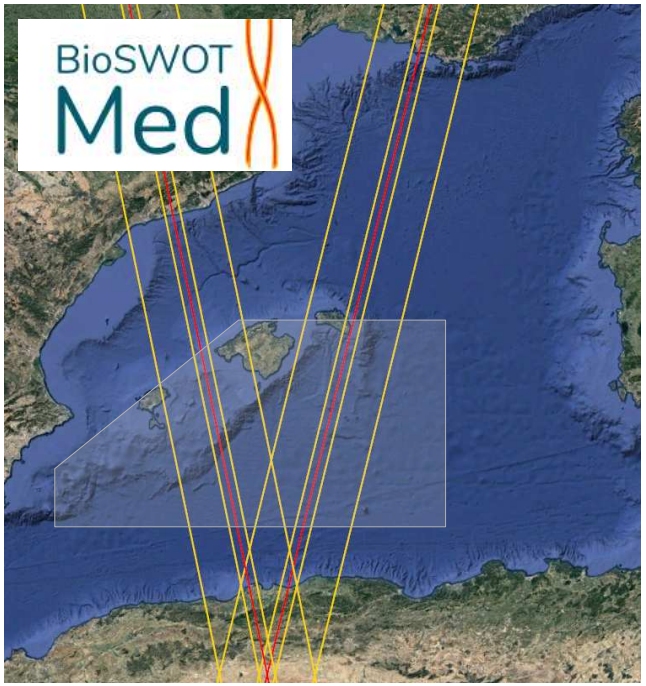
PIs A.M.Doglioli and G.Grégori

The BioSWOT-AdAC cruise
in the SW Mediterranean Sea

SWOT
SURFACE WATER & OCEAN TOPOGRAPHY
NASA • CNES • CSA • UKSA

SWOT AdAC



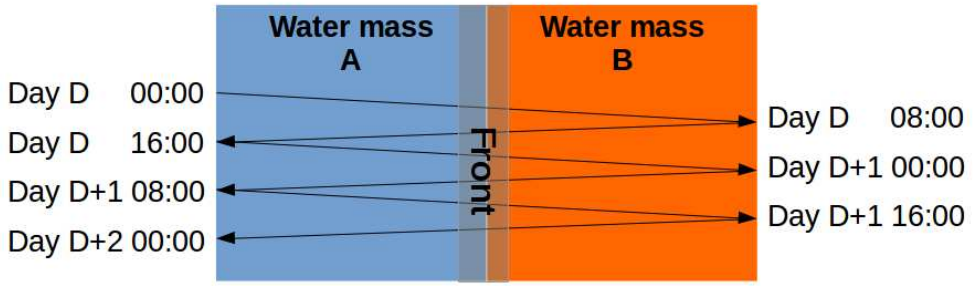


Strategy and methodology

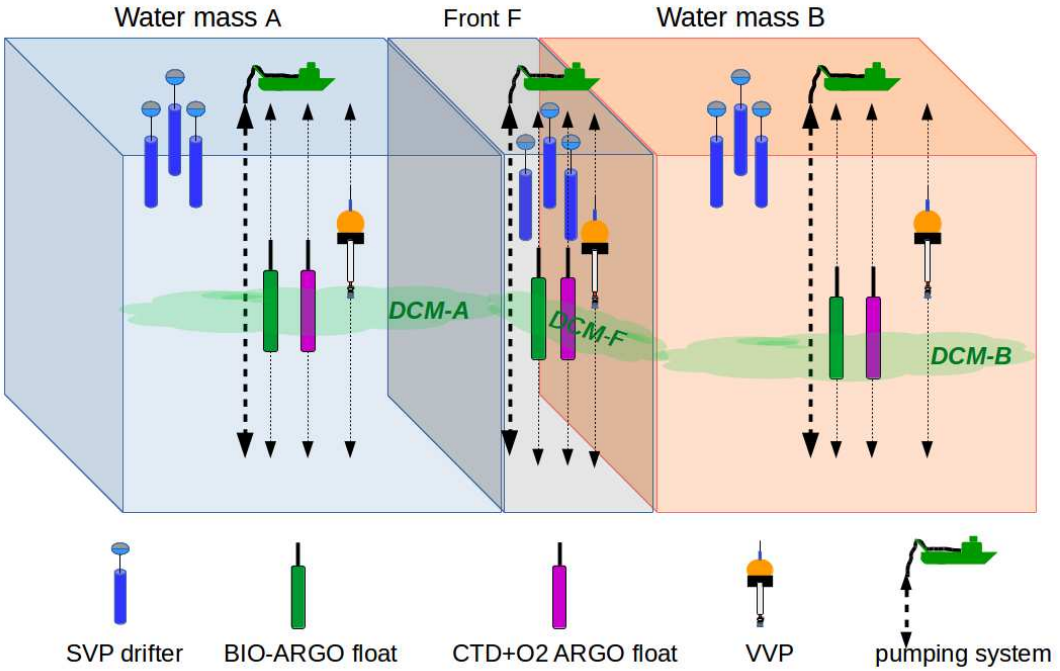
adaptive Lagrangian sampling strategies & Innovative instrumentation

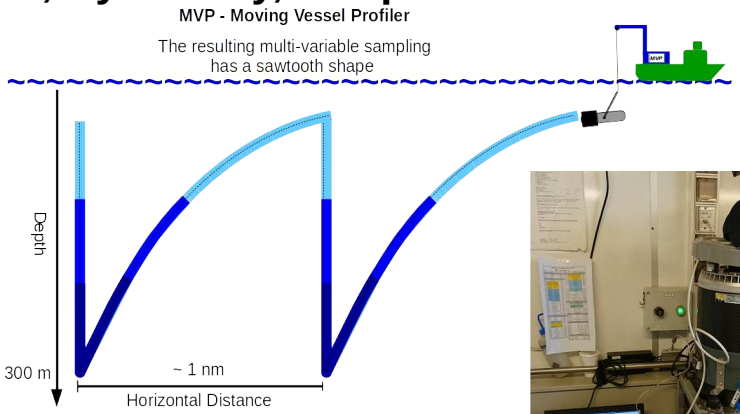
SPASSO & MVP, gliders, AUV, drifters & floats, FFADCP, VVP, Cytometry, zooplankton and omics

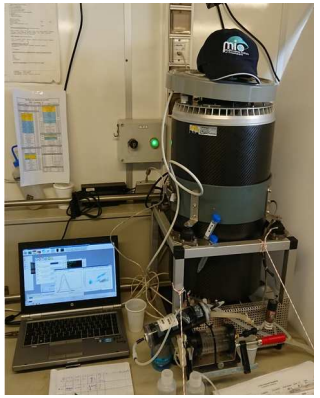
« back and forth » strategy for the horizontal continous sampling

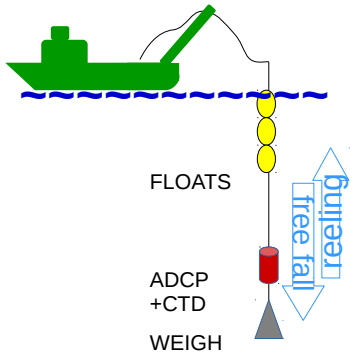


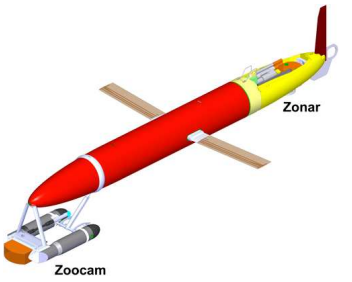
« Lagrangian stations» strategy for the vertical sampling

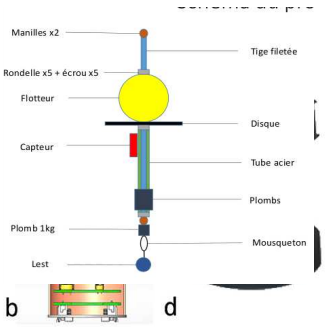


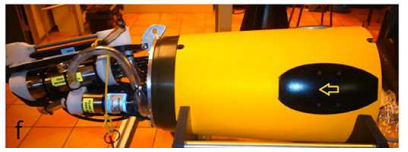












1) vertical advection

From altimetry to *w*

Numerous works (e.g. Lapeyre, G., & Klein, P. (2006), Qiu et al, 2016,2020, Pietri et al 2021)
show a need of :

in situ direct measurement of the balanced *w*
(Med Sea ideal conditions with no tide)
in particular in the surface layer

associated with

- Mixing microstructure measurment

- High resolution ctd cast

- Horizontal vorticity

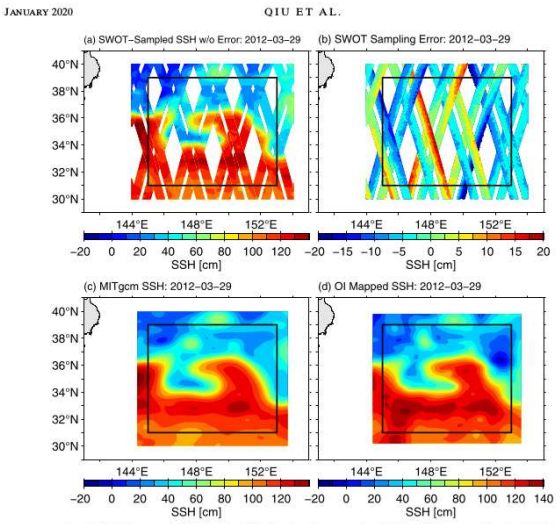
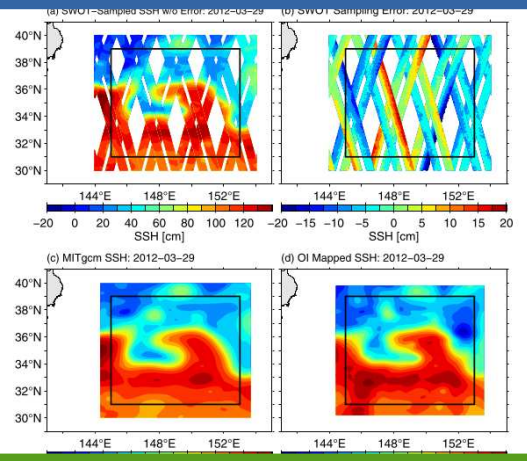


FIG. 10. (a) Along-swath SSH signals within the subcycle centered on 29 Mar 2012 generated by the SWOT simulator based on the hourly LLC4320 output. (b) SWOT simulator-generated along-swath SSH measurement errors. Note that the color scale for (b) is different from that in (a). (c) LLC4320 SSH map on 29 Mar 2012 after low-pass filtering by Eq. (1). (d) Objectively mapped SSH field on 29 Mar 2012 from the SSH input of (a) + (b).

1) vertical advection



From altimetry to *w*

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in situ direct measurement of the balanced *w* (Med Sea ideal conditions with no tide) in particular in the surface layer

associated with

- Mixing microstructure measurment

- High resolution ctd cast

- Horizontal vorticity

Our strategy :

*BIOSWOT-**Med***

Innovative methods :
5-beams acoustic (FFADCP) & buoyancy profiler (VVP)

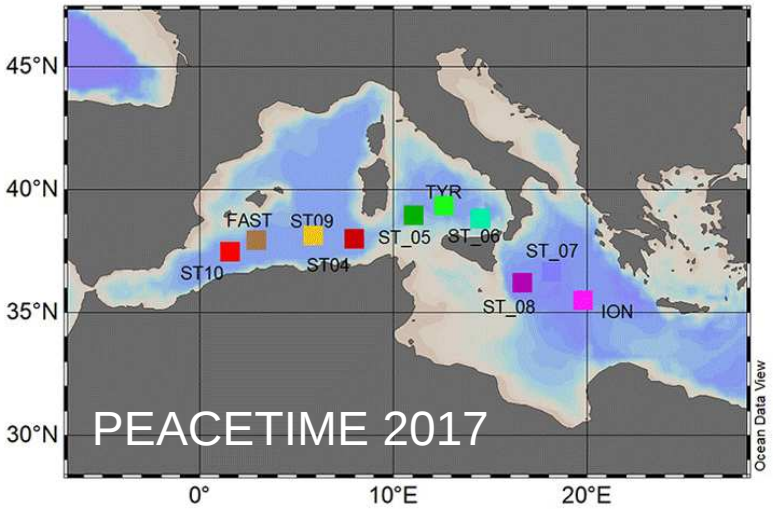
Turbulence profiler (VMP)

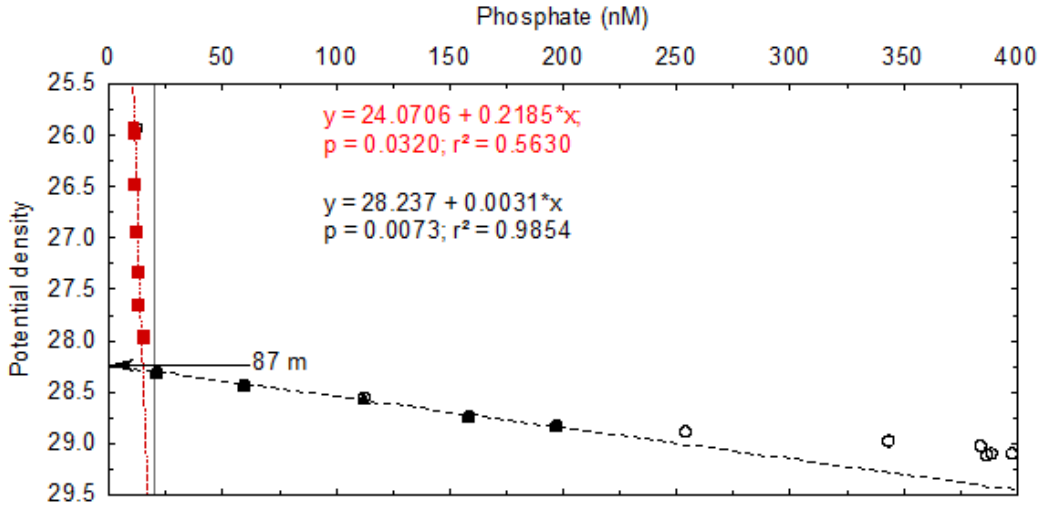
Towed fish (MVP/SeaSoar)
Argo drifting profilers
gliders

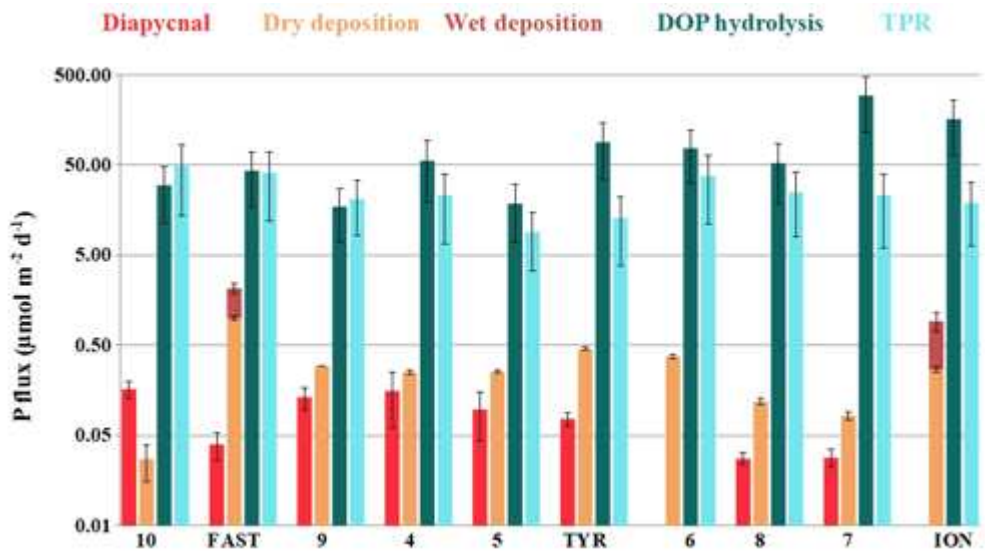
hull mounted ADCP and surface drifters

2) nutrients

[Pulido-Villena et al. 2021]







Highly dynamic phosphorus pool in the upper layer.

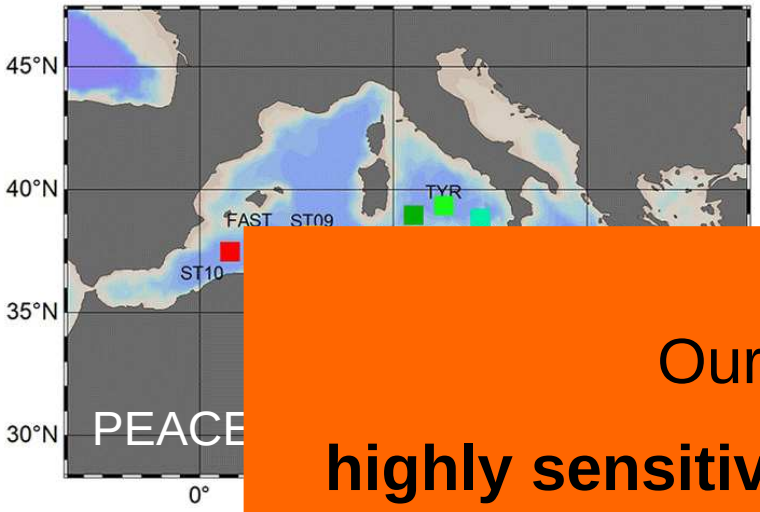
A new paradigm :

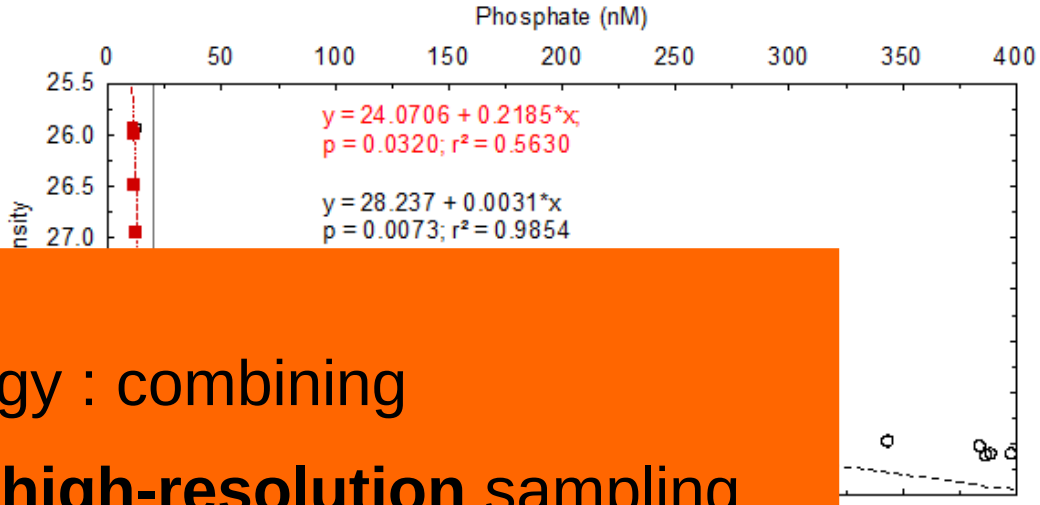
the surface layer of the Mediterranean Sea receive new P NOT exclusively from the atmosphere,

diapycnal fluxes are also important !

2) nutrients

[Pulido-Villena et al. 2021]



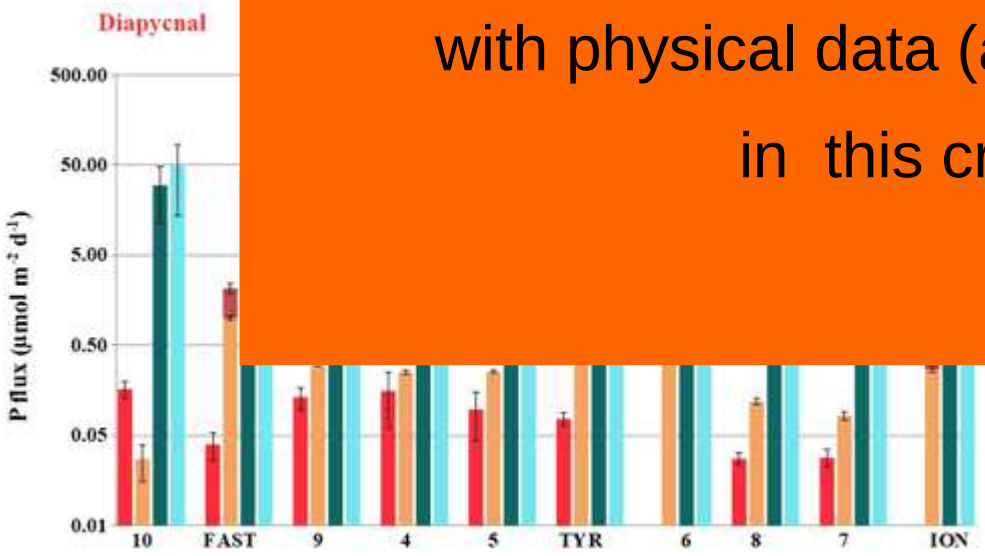


Our strategy : combining

highly sensitive and **high-resolution** sampling

with physical data (**advection & mixing**)

in this crucial layer



n the

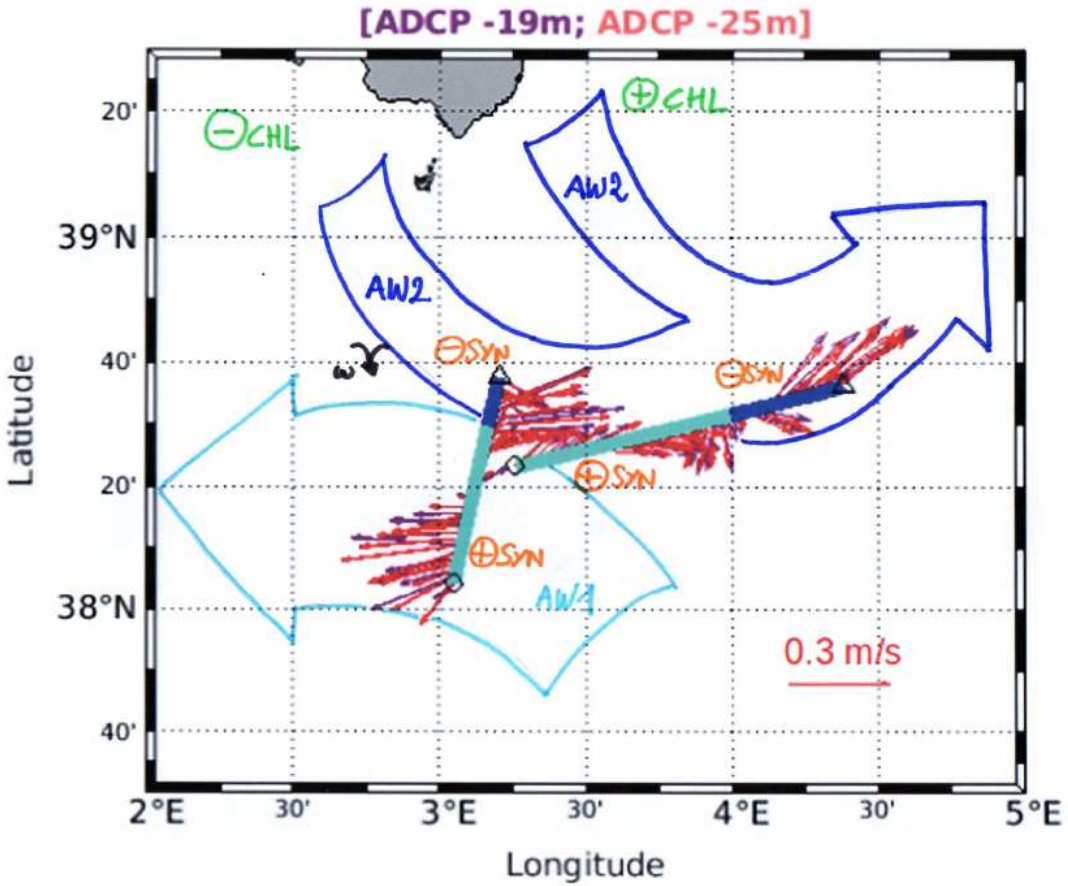
nean

Sea receive new P NOT exclusively from the atmosphere,

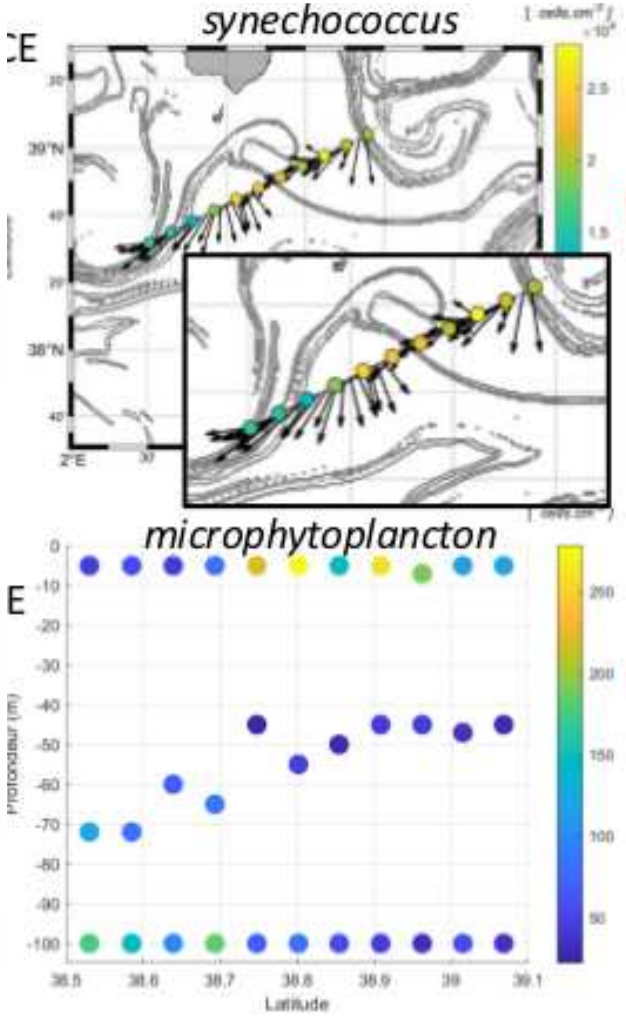
diapycnal fluxes are also important !

3) fluidodynamical niches

During the preparation cruise in 2018 :
strong strcturing effect of the finescale circulation
on the plankton abundance distribution



[Tzortzis et al, 2021]



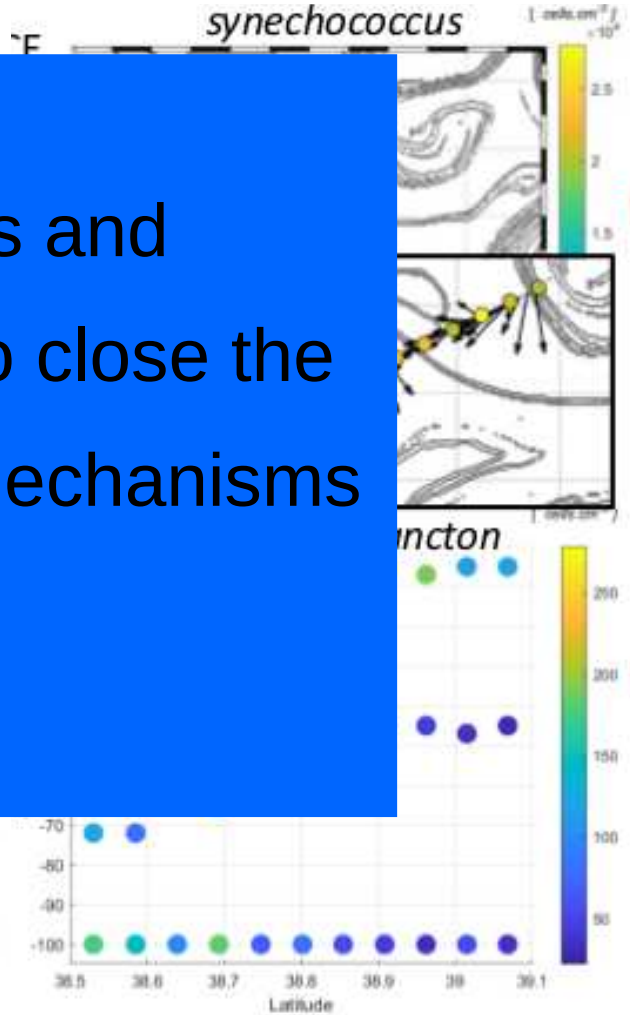
[Oms, M2 report, 2022]

3) fluidodynamical niches

During the preparation cruise in 2018 :
strong strcturing effect of the finescale circulation
on the plankton abundance distribution

Our strategy : nutrients and zooplankton grazing data to close the budget and to understand mechanisms involved

[Tzortzis et al, 2021]



[Oms, M2 report, 2022]

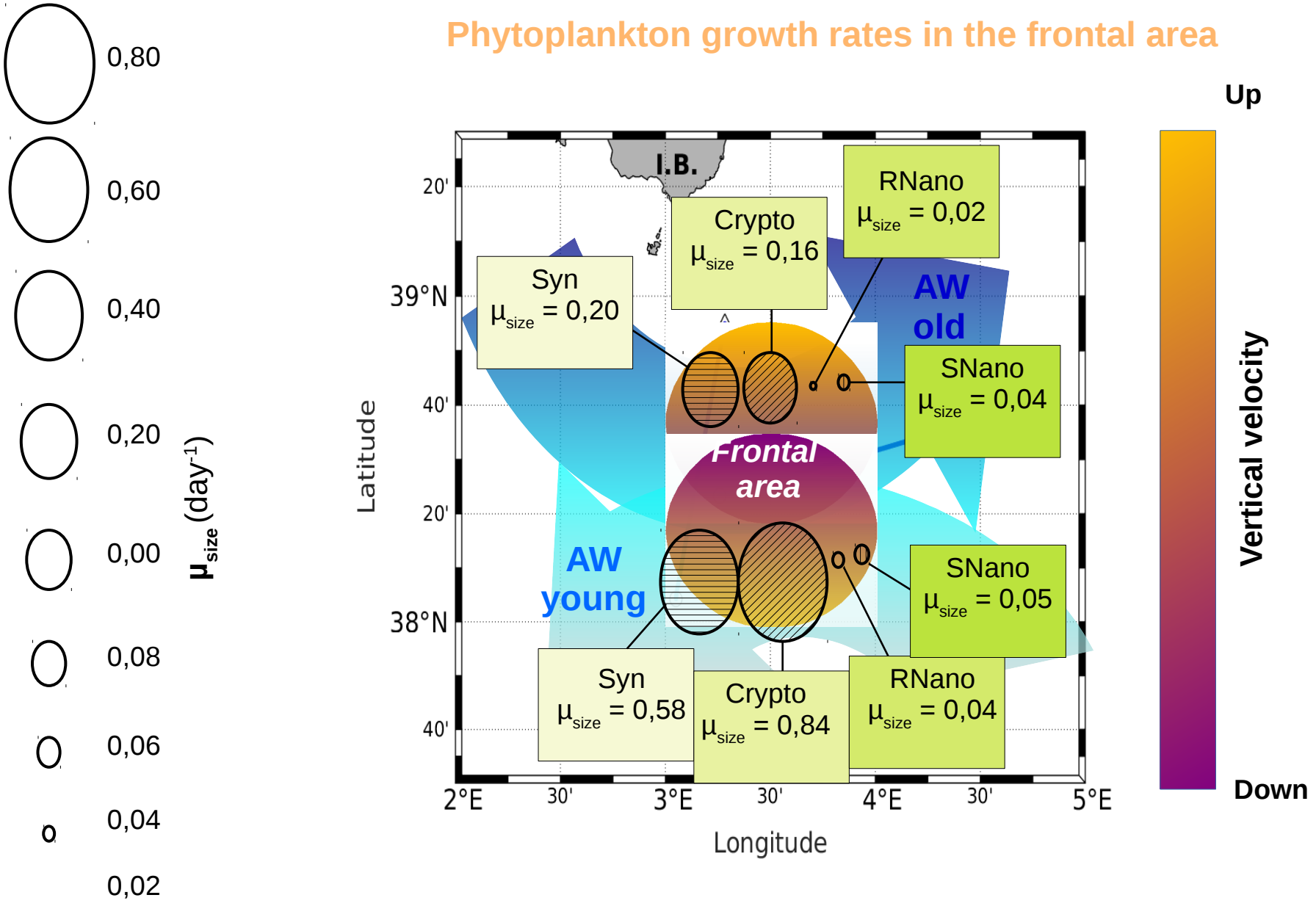
BioSWOT Med

R/V l'Atalante

21 April 2023 – 14 May 2023

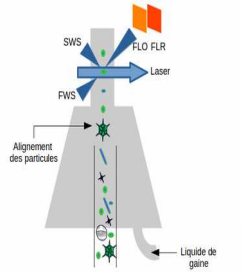

Merci de votre attention !
Questions ?

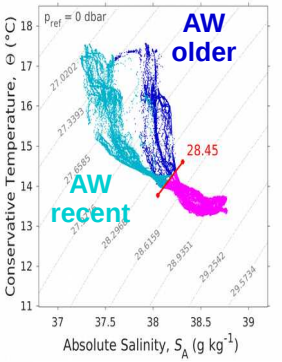
EXTRA SLIDES

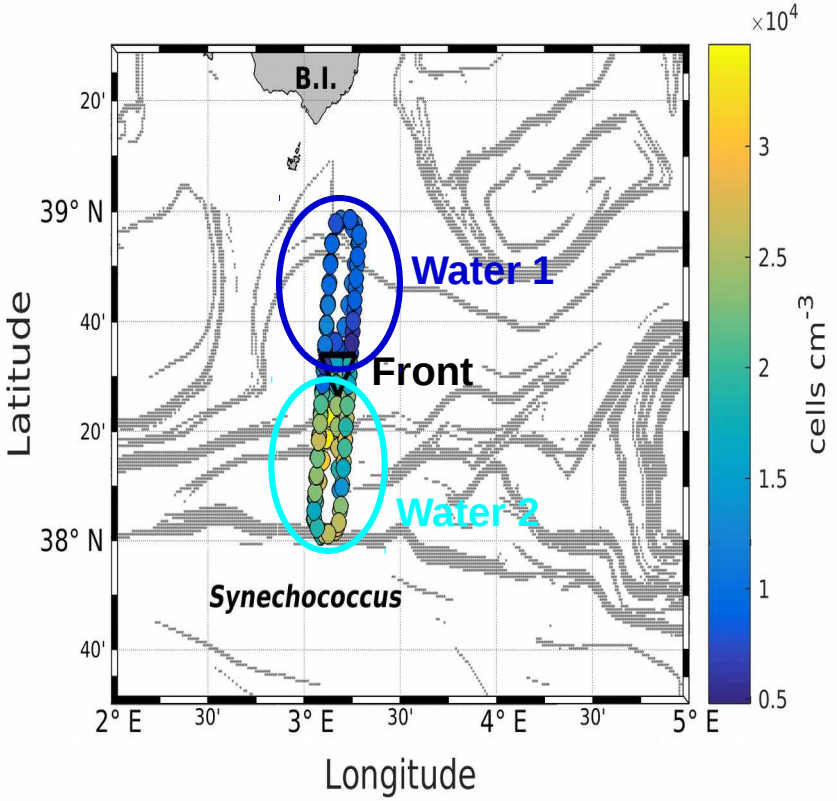

Phytoplankton growth rates in the frontal area
0,80
0,60
0,40
0,20
0,00
0,08
0,06
0,04
0,02
μsize (day-1)
I.B.
RNano
μsize = 0,02
Crypto
μsize = 0,16
Syn
μsize = 0,20
AW
old
SNano
μsize = 0,04
Frontal
area
AW
young
SNano
μsize = 0,05
Syn
μsize = 0,58
Crypto
μsize = 0,84
RNano
μsize = 0,04
20'
39°N
40'
20'
38°N
40'
2°E
30'
3°E
30'
4°E
30'
5°E
Latitude
Longitude
Up
Vertical velocity
Down

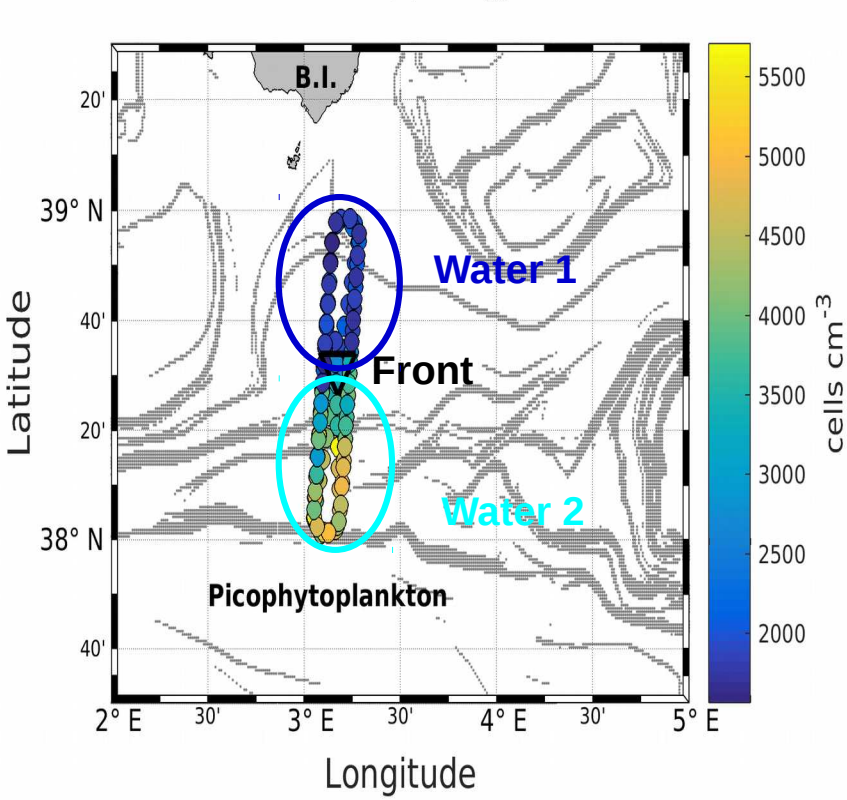
Selection of the data in the hippo NS

→ Water 1 and Water 2 separated by the front at ~ 38.5 N°.



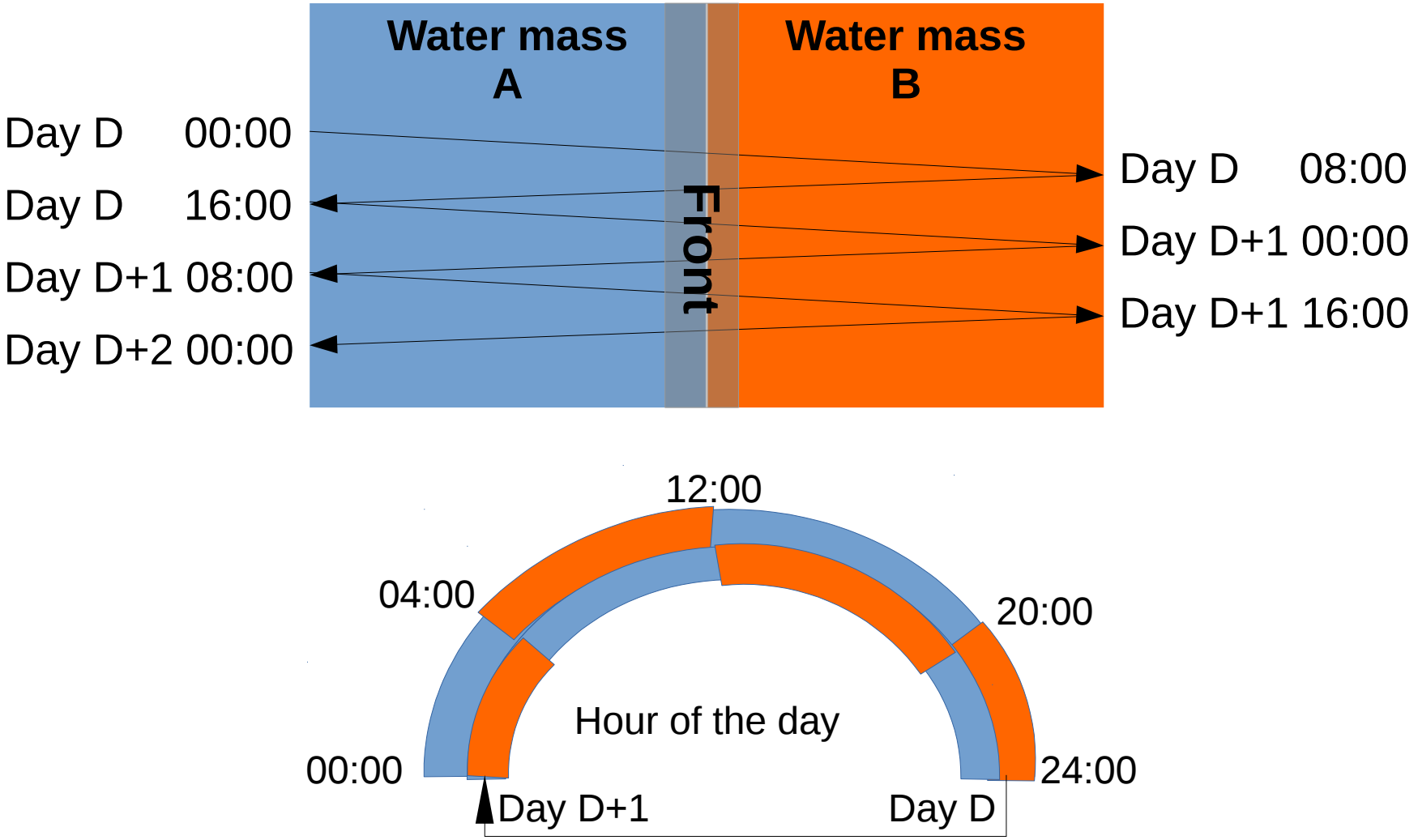




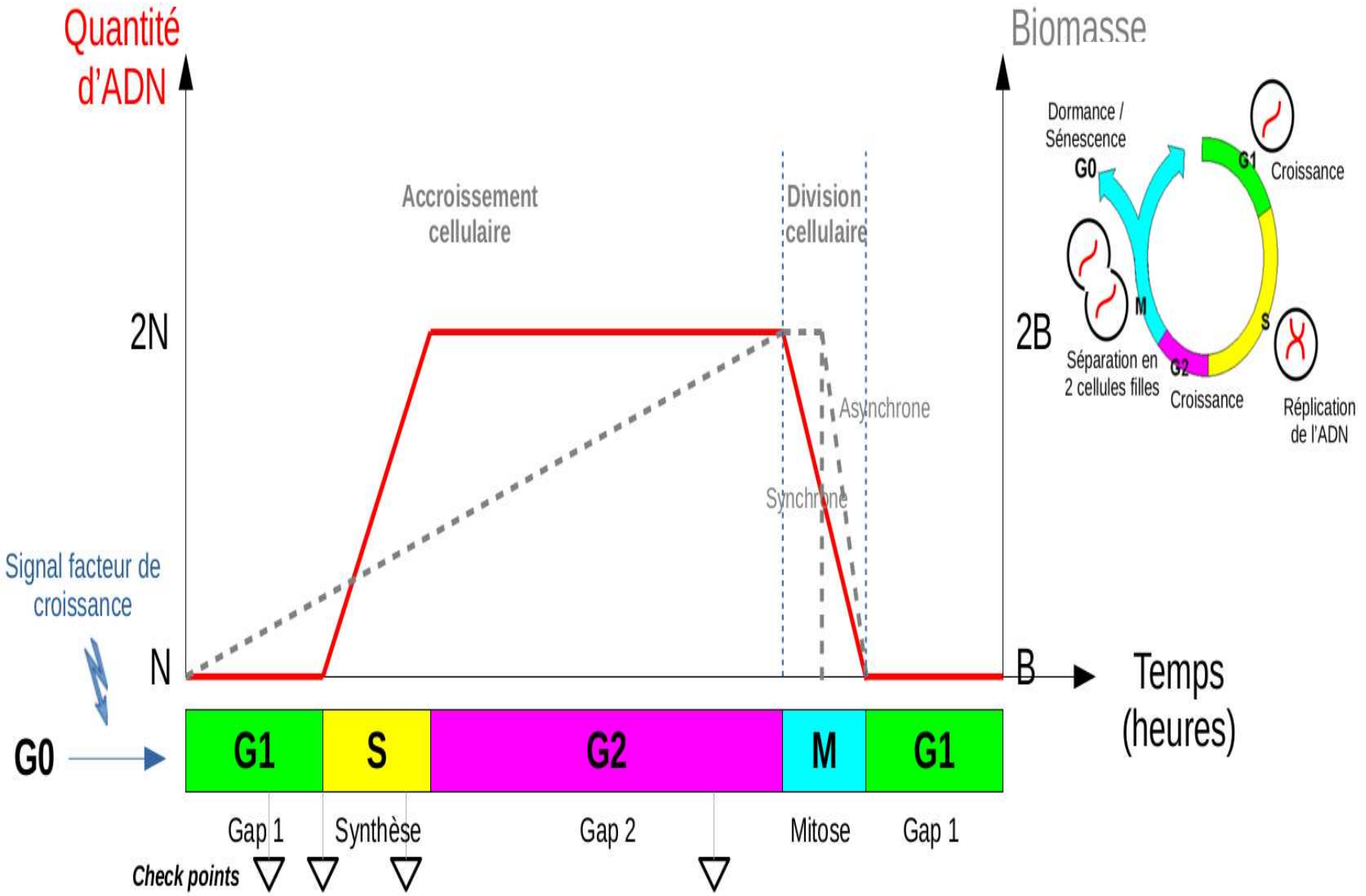


Hippo NS :
11 May 2018 –
13 May 2018

« back and forth » strategy for the horizontal continous sampling

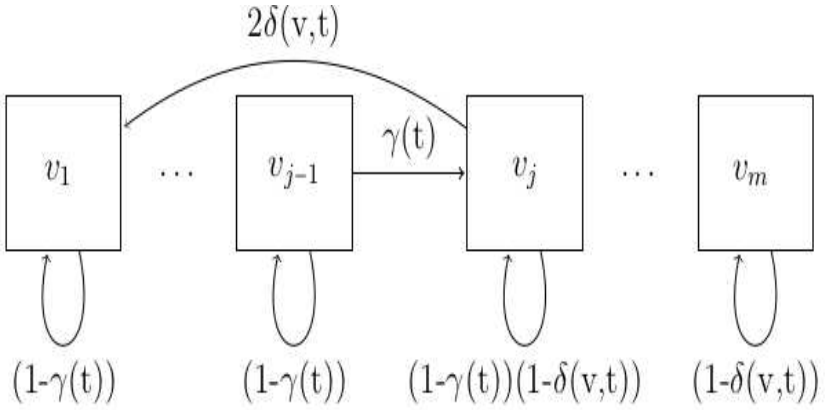


Performing 8-hours transects, it is possible to cover the entire life cycle in 2 days


Quantité d'ADN
Biomasse
Accroissement cellulaire
Division cellulaire
2N
N
2B
B
Asynchrone
Synchrone
Signal facteur de croissance
G0
G1
S
G2
M
G1
Gap 1
Synthèse
Gap 2
Mitose
Gap 1
Check points
Temps (heures)
Dormance / Sénescence
G0
G1
Croissance
M
S
G2
Séparation en 2 cellules filles
Croissance
Réplication de l'ADN

The size-structured population model (Sosik et al., 2003)

Cells transit in the different size classes upon a circadian clock regulating the cell cycle.



- **Probability of cells growing, depends on the light intensity**

$$\gamma(t) = \gamma_{max}\left[1 - exp\left(-\frac{E(t)}{E^*}\right)\right]$$

→ E : light intensity (PAR)
→ E* : constant
→ γ : proportion of cells
→ γ_{max} : constant

- **Probability of cells entering in mitosis**

$$\delta(t,v) = \delta_{max}\mathcal{N}(\mu_v,\sigma_v)\mathcal{N}(\mu_t,\sigma_t)$$

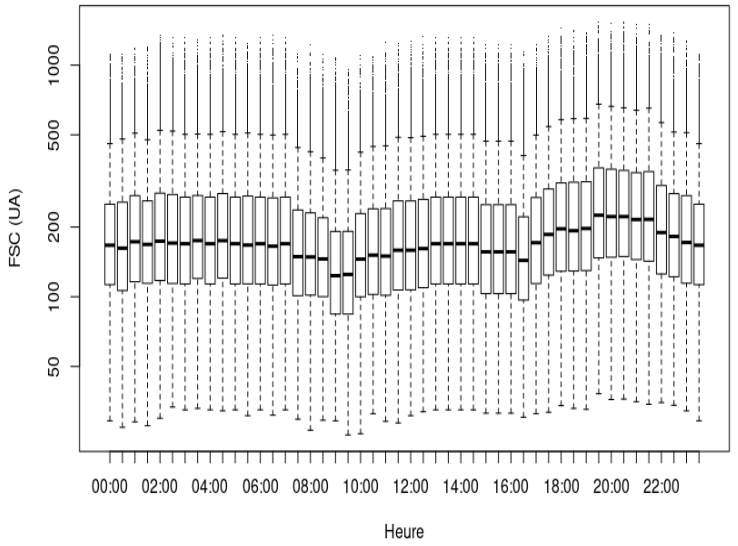
- **Growth rates**

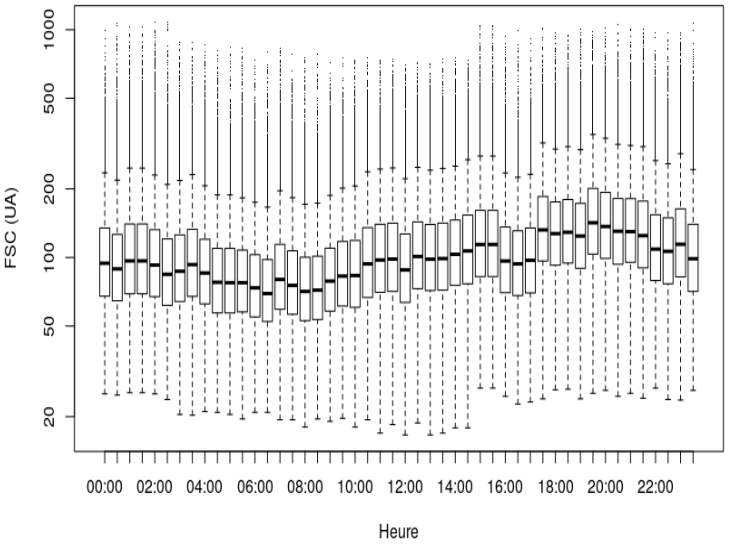
$$\mu_{size} = \frac{1}{t+dt}log_e\left(\frac{\hat{N}(t+dt)}{N(t)}\right)$$

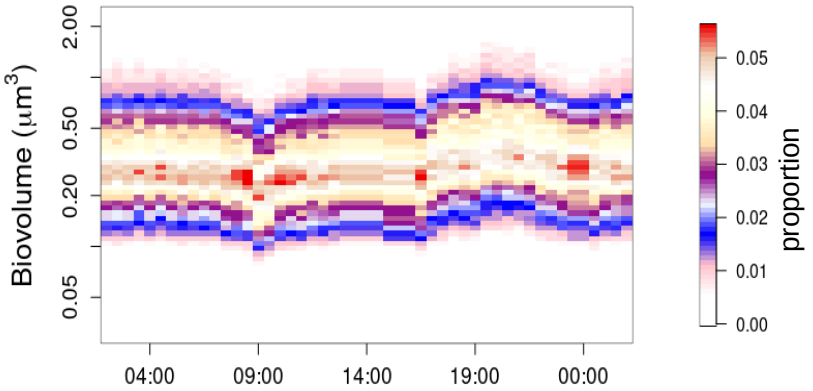
→ μ : growth rates
→ N : number (proportion) of cells in size classes
→ t : time

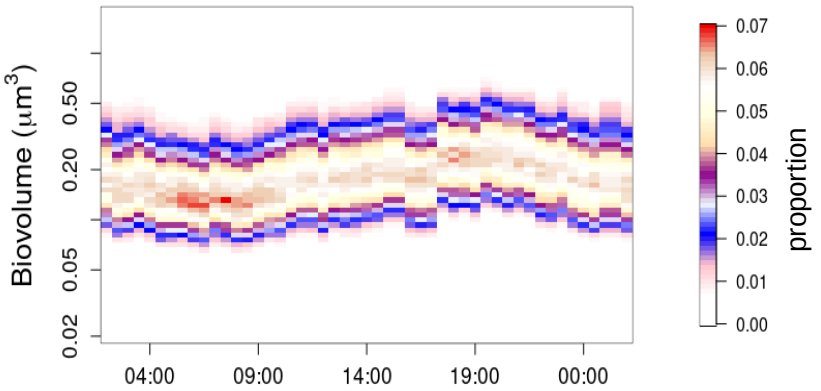
Convert FWS into biovolume

- ***Synechococcus***

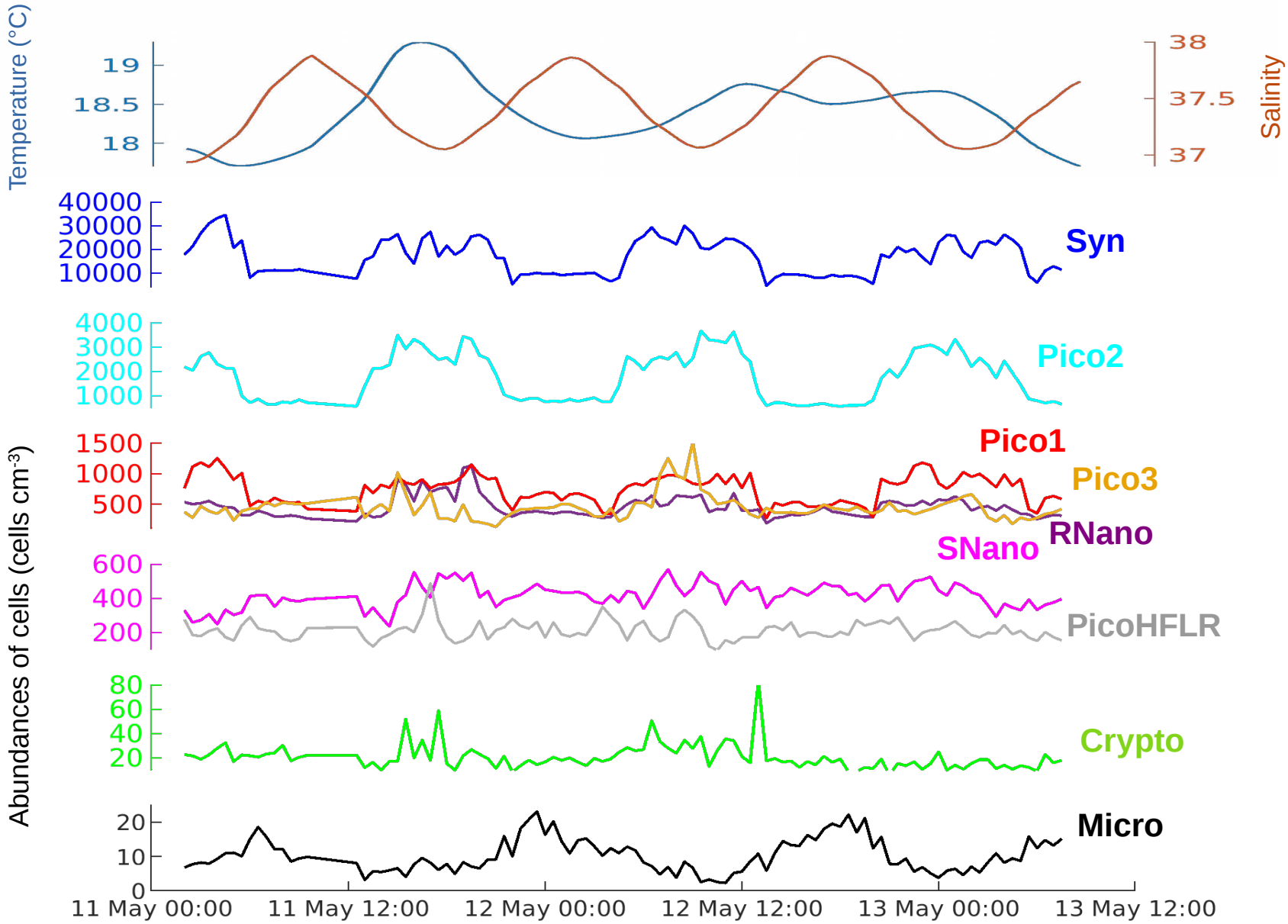


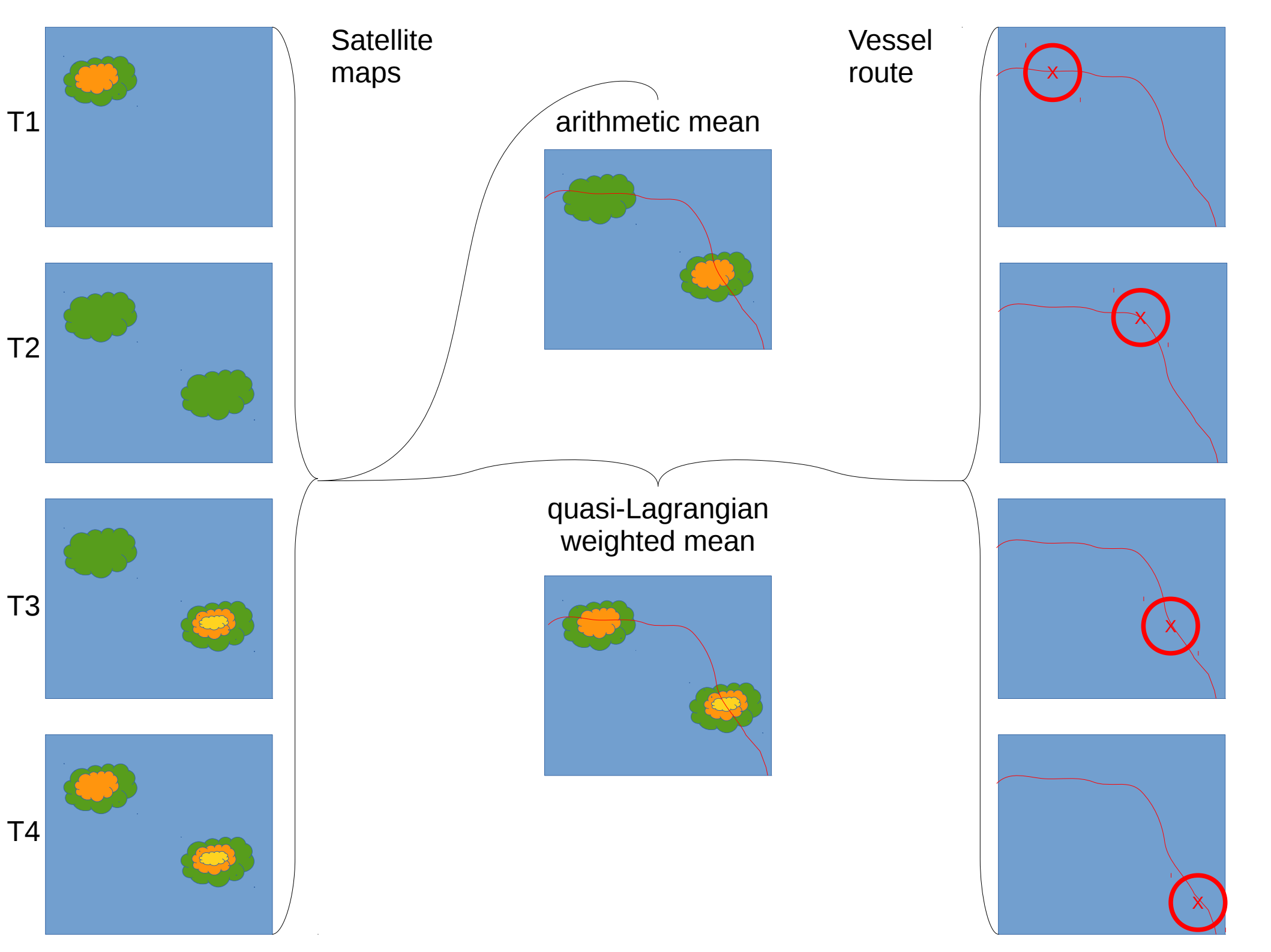






PROTEVSMED_SWOT 2018




Satellite maps
Vessel route
T1
T2
T3
T4
arithmetic mean
quasi-Lagrangian weighted mean
X
X
X
X

Materials and Methods

High resolution vertical sampling

CTD carousel

ECOVSF3
Three-angle, Three-wavelength
Volume Scattering Function Meter

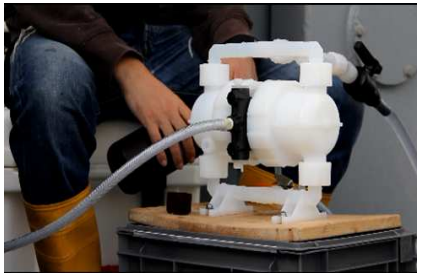
CTD SBE32

LOPC and LISST
Laser Optical Particle Counter

Laser In situ scatterometer and transmissiometer

PASTIS

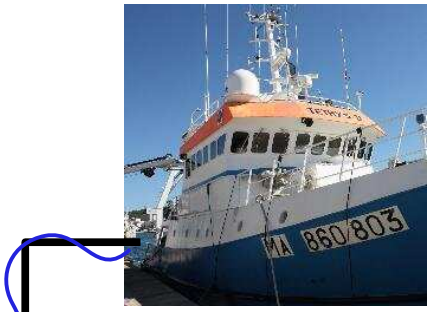
Pumping **A**dvanced **S**ystem **T**o **I**nvestigate **S**eawater

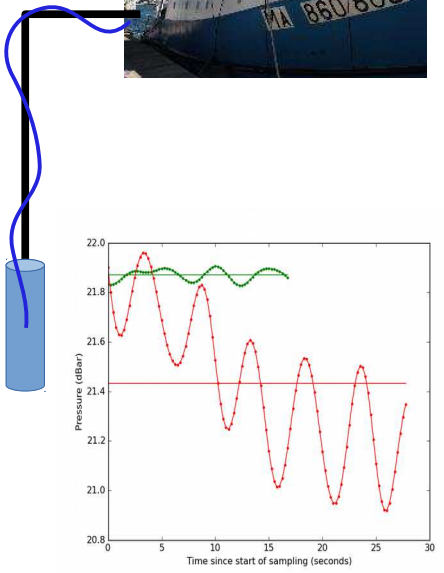


- bellows pump
- 30m PE tube
- CTD SBE19+

Discrete Sampling

vertical precision 0.1 to 1 m





Post-Cruise
Lab Analysis:
Nutrients and Cytometer FACScalibur

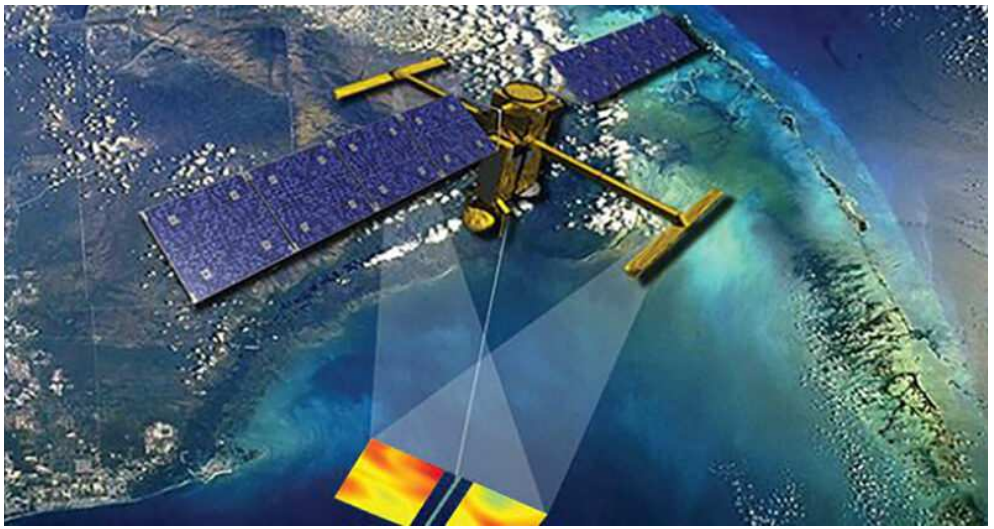
What is the impact of the ocean fine scales on phytoplankton diversity?

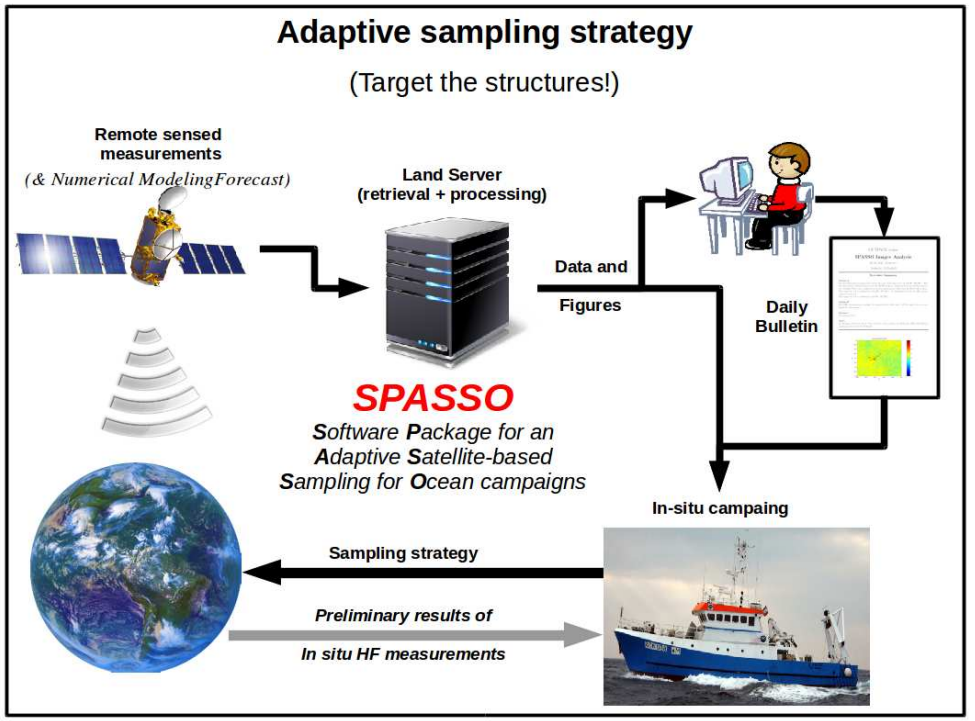
Next-generation tools for the fine scales

Dense observations allow assimilation models to provide very realistic and high resolution fields

Preparatory cruises (OSCAHR 2015, PROTEVSMED_SWOT 2018, FUMSECK 2019) to study the feasibility of a finescale campaign were succeful

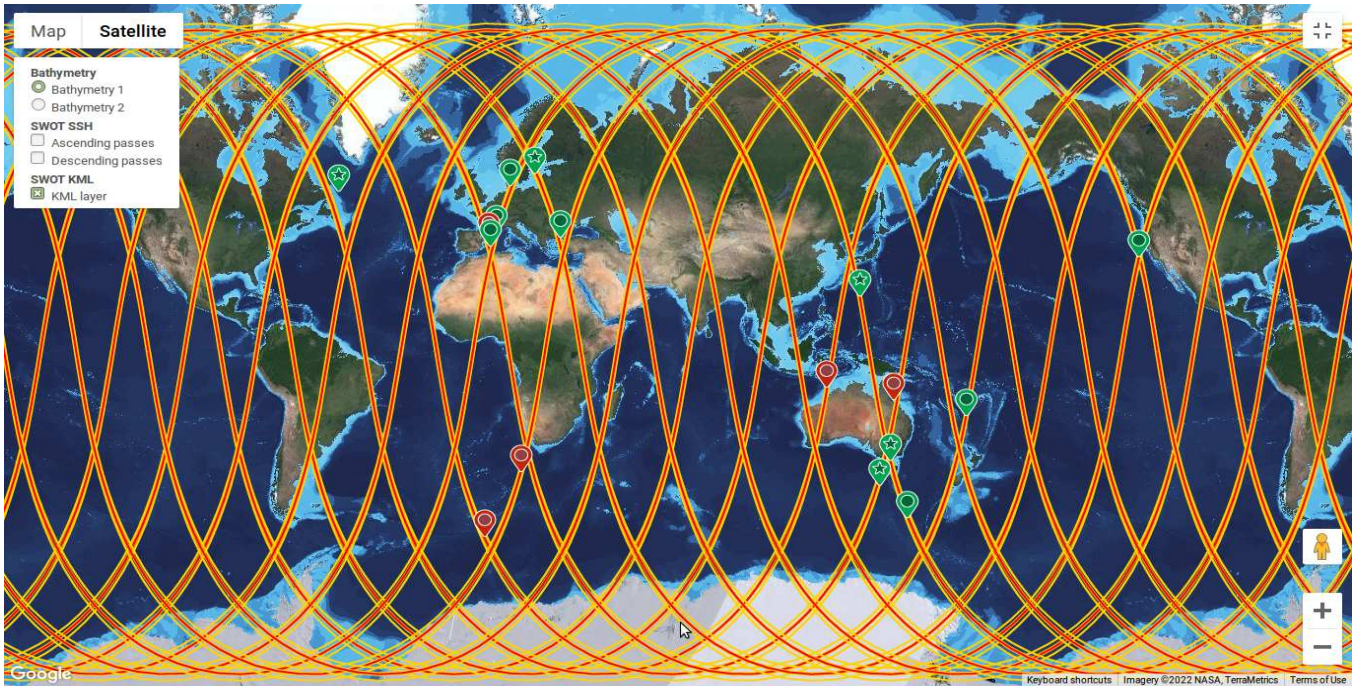
And now...
we will benefit of the satellite mission SWOT!





BIOSWOT-Med is part of the SWOT Adopt-a-Crossover Consortium

https://www.swot-adac.org

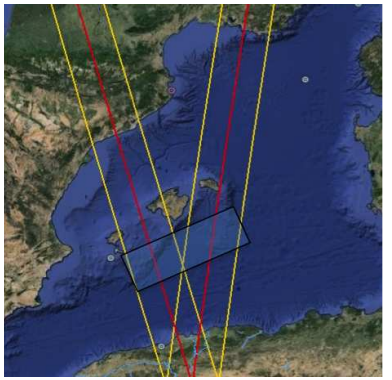


Currently 11 campaigns (at various level of maturity) have been proposed.

BIOSWOT-Med and the California campaigns are the leading members, thanks to the strong supported by CNES and NASA !

BIOSWOT-Med campaign PIs: A. Doglioli, G. Grégori	*21 avril- 14 may*	*2023*
BIOSWOT-CSWOT campaign PIs: F. Dumas, P. Garreau	*23 march – 18 avril*	
BIOSWOT-CapeCauldron campaign PI: S. Speich		*2024*

PROTEVSMED_SWOT 2018



A synergy among three programs in the SW Mediterranean:

- PRE-SWOT (A. Pascual)
- PROTEVS_SWOT (F. Dumas, P. Garreau)
- BIOSWOT (F. d'Ovidio, A. Doglioli, G. Grégori, F. Cyr)

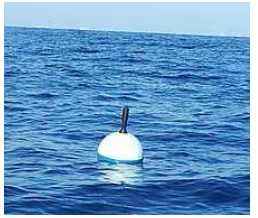
A multi-platform and multi-methods campaign :

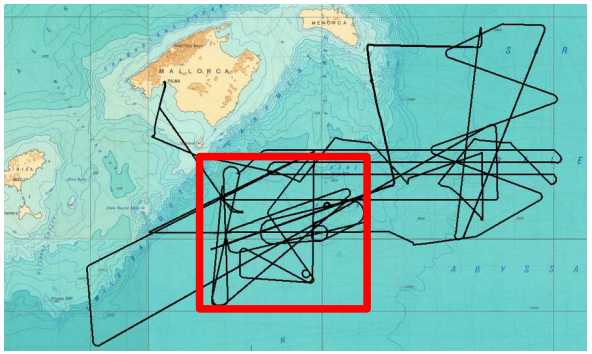
BHO Beautemps-Beaupré
(SHOM, France)
28 Avril-14 May 2018

R/V García del Cid
(CSIC, Spain)
5-17 May 2018

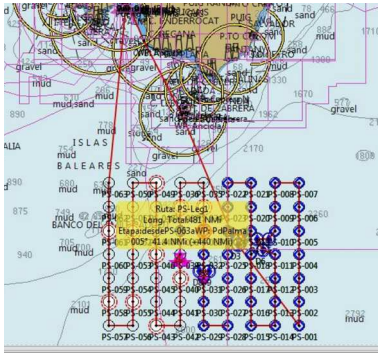
Gliders
(MIO & SOCIB)

Drifters
(CSIC, SOCIB, SHOM)

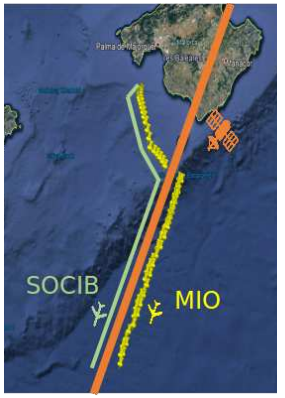




Lagrangian sampling area



Eulerian sampling area



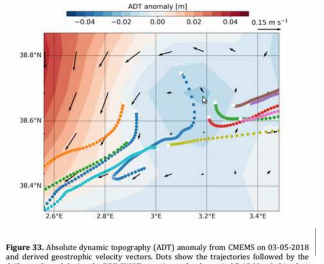


Figure 33. Absolute dynamic topography (ADT) anomaly from CMEMS on 03-05-2018 and derived geostrophic velocity vectors. Dots show the trajectories followed by the drifters released during the PRE-SWOT experiment for the period 5-13 May (white dots are the release positions).

Comment mesurer les vitesses verticales avec SWOT ?

From altimetry to *w*

Two approaches :

1) statistical

regressions high-resolution SSH/SST & in situ temperature–salinity data
-> to empirically infer the 3D upper-ocean structures.
Mesoscale (e.g., Guinehut et al. 2004; Buongiorno-Nardelli et al. 2012; Mulet et al. 2012)

2) dynamical

deduced from climatological observations.

Lapeyre and Klein [2006] Antartic Circumpolar Current :

correlation surface & interior PV anomalies = correlation large-scale surface & interior PV

→ The upper-ocean circulation structures are reconstructable from the 3D PV inversion with the use of only high-resolution surface information and interior ocean climatology.

effective surface quasi-geostrophic (SQG) is the simplest reconstruction interior PV through an effective buoyancy frequency (as SQG model with nonzero surface PV and zero interior PV, Blumen 1978; Held et al.1995).

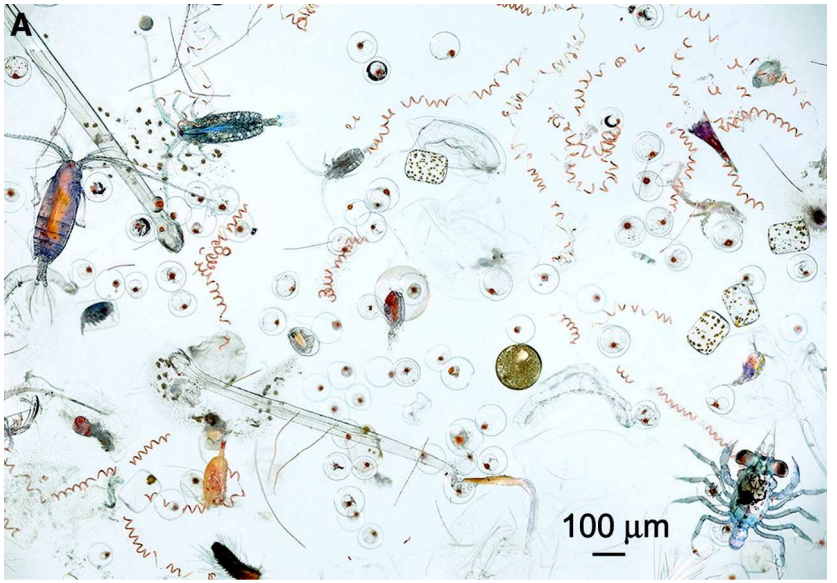
Applications :
- LaCasce and Mahadevan (2006) off California, Alboran Sea, Azores Front.
- Isern-Fontanet et al. (2006, 2008) North Atlantic Ocean
- Klein et al. (2009), Smith and Vanneste (2013) Idealized simulations

6. What are the differences between the Pico and Nano plankton groups to differentiate them?

Plankton categories based on a logarithmic size scale:

Macroplankton (200–2000 µm)

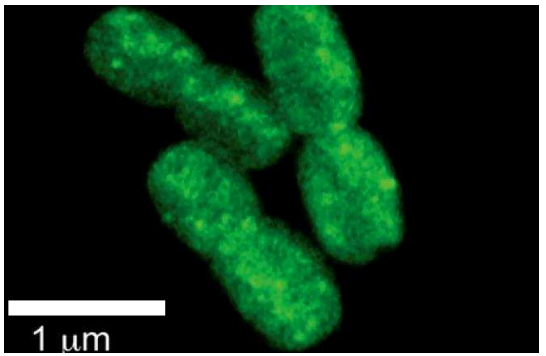
Microplankton (20–200 µm)

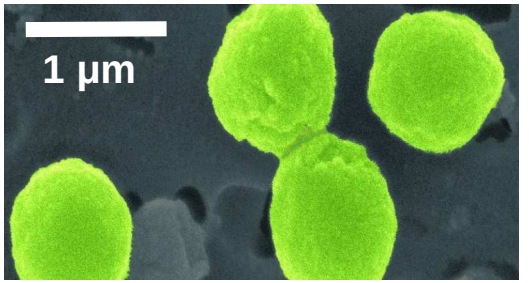


Nanoplankton (2–20 µm)

Picoplankton (0.2-2 µm)

Femtoplankton (0.02-0.2 µm)





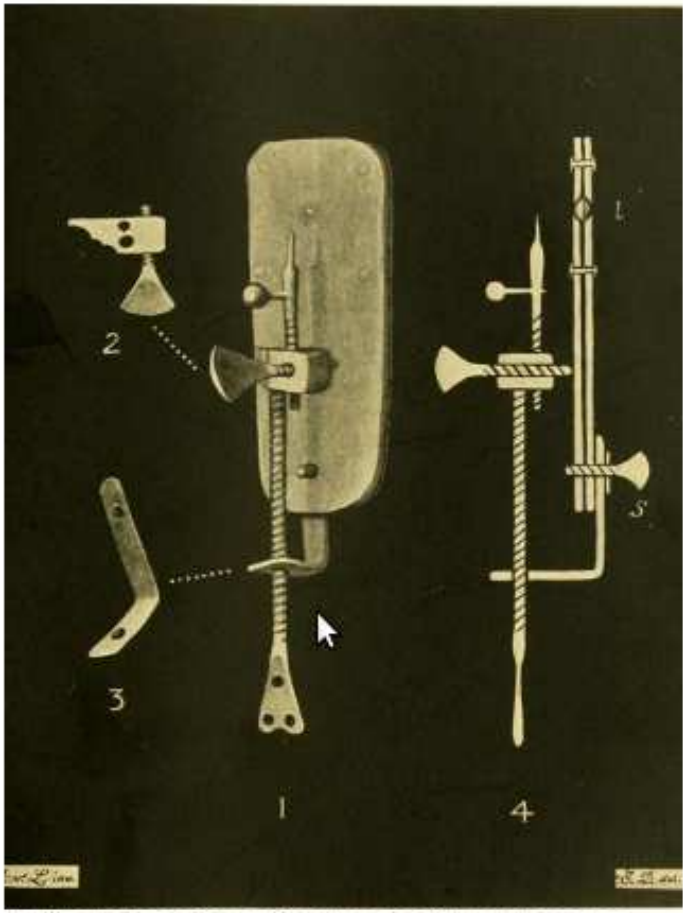
The marine microbiology

1675

The Dutch lensmaker A. van Leeuwenhoek devises a simple (yet powerful 1:300) microscope that allows him to observe microbes for the first time.

Antoine van Leeuwenhoek
Delft, 24 octobre 1632
Delft, 26 août 1723

Colored engravings of the "animalcules" Leeuwenhoek saw under his microscope. Credit: Anton van Leeuwenhoek. U.S. Public Domain



An illustration of one of Leeuwenhoek's microscopes. Credit: Dobell and van Leeuwenhoek, 1960

https://ocean.si.edu/milestones-marine-microbiology