A Lagrangian strategy for in situ sampling of the physical-biological coupling at fine scale : the PROTEVSMED-SWOT 2018 cruise

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See also the abstract EGU2020-7357
https://doi.org/10.5194/egusphere-egu2020-7357

1. Context : Fine scale biophysical processes

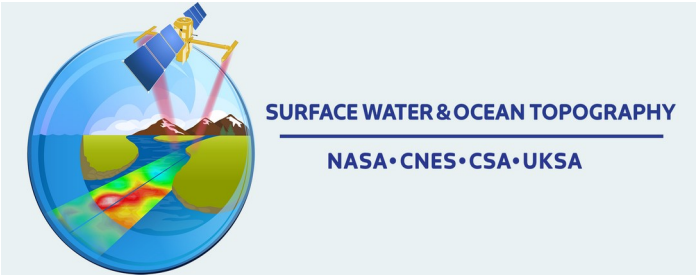
- **Fine scale's characteristics :** Horizontal scales smaller than **10 km** with a **short lifetime** (days/weeks).
  - Predominantly studied with **numerical simulations** and **observations of ocean color** and **Sea Surface Temperature (SST)**.
  - A real **challenge** to sample these structures **in situ**.

- **Modellers** highlight the impact of fine scale circulation on :
  - **Biogeochemistry** : impacts the carbon pump, advecting nutrients upward and organic matter downward (Lévy et al., 2001 ; Mahadevan, 2016) .
  - **Biological processes** : **fronts** and **filaments** strongly influence the **distribution** of **phytoplankton species** (d'Ovidio et al., 2010) .

- The **combination** of in **situ measurements**, **satellite observations** and **model simulations** is a necessity to **better understand** these mechanisms (Marrec et al., 2018).

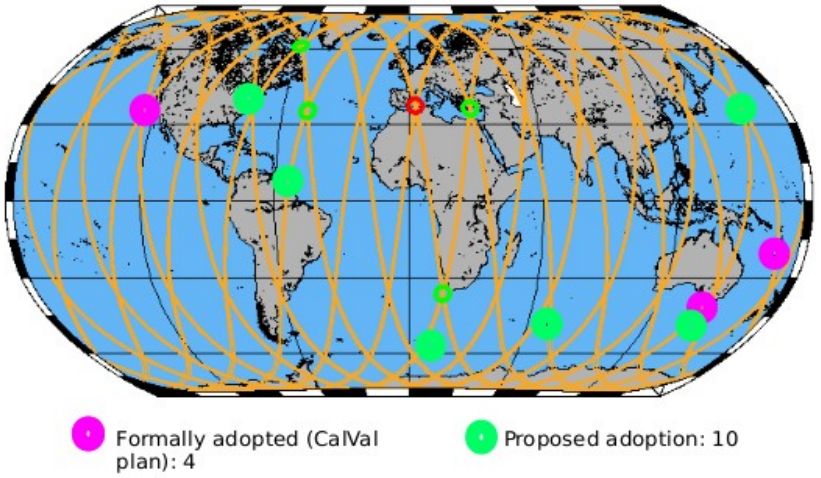
1. Context : BIOSWOT project

- **SWOT** : New generation of **altimetric satellite** will provide :
  - A 2D sea surface height at an **unprecedented resolution**.
  - A unique opportunity to better **observe fine scale** structures in the global ocean.



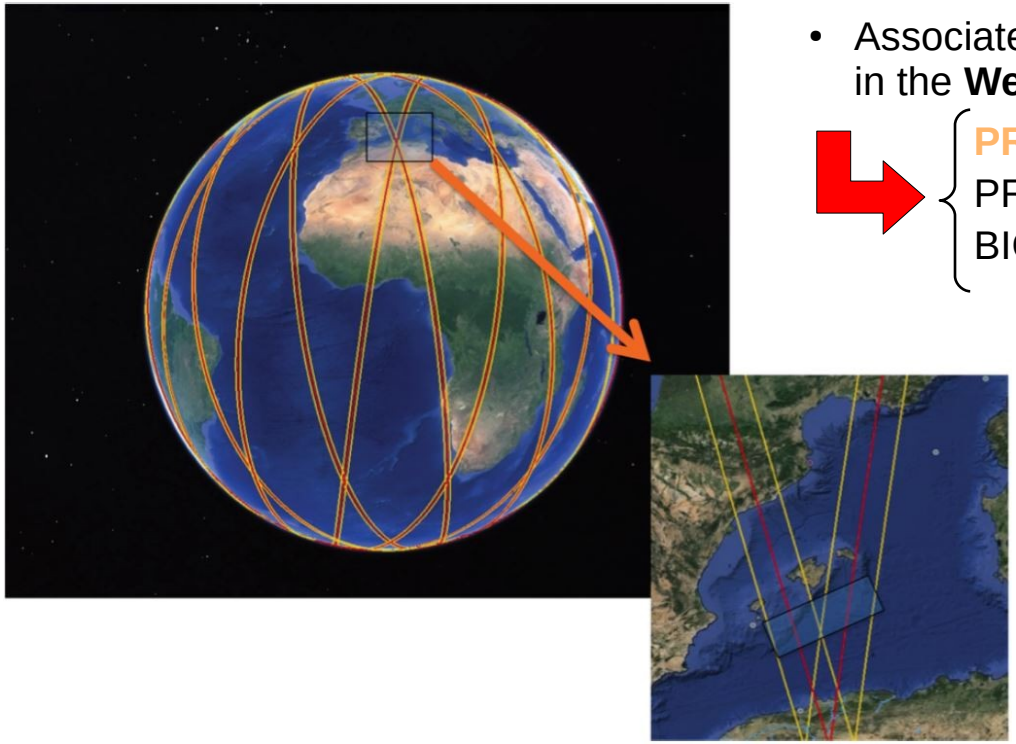
Launch planned for 2022

- **“Adopt a SWOT crossover”** initiative (d’Ovidio et al., 2019) :
  - **Crossover** : Crossing point distributed **all around the globe**, with a **temporal resolution of one day** (during the few months after launch).
  - **"Adopt a crossover initiative"** : Encourages the international scientific community to **coordinate future cruises** in the crossover’s areas, **before** and **during** the SWOT mission.



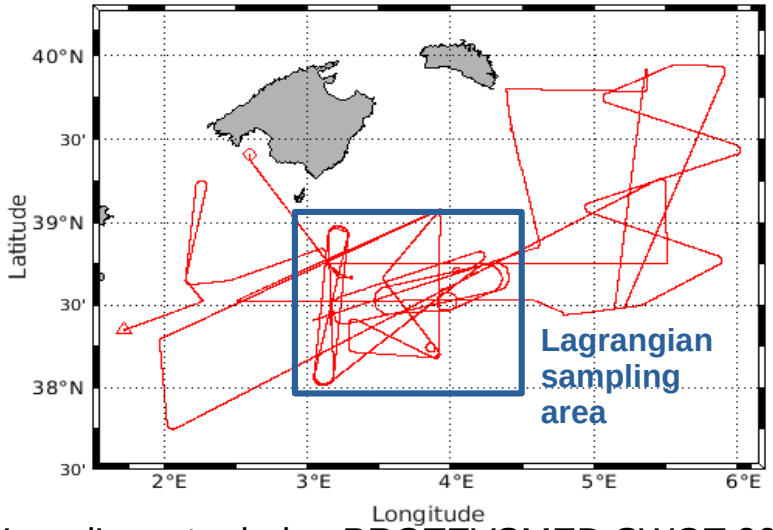
Goals : Calibrate and validate SWOT’s datas, synergy between in situ and satellite data.

1. Context : PROTEVSMED-SWOT 2018 cruise



SWOT's crossover in the Western Mediterranean Sea, near the Balearic Island.
Figure extracted from Barceló-Llull et al., 2018.

- Associated **cruises** in the area of **SWOT's crossover** in the **Western Mediterranean Sea** :
  - **PROTEVSMED-SWOT 2018** (PI : F. Dumas)
  - PRE-SWOT 2018 (PIs : A. Pascual and J. T. Allen)
  - BIOSWOT 2022 (PI : F. d'Ovidio ; co-PIs : A. M. Doglioli and G. Grégori)



Vessel's route during PROTEVSMED SWOT 2018

1. Context : PROTEVSMED-SWOT 2018 cruise

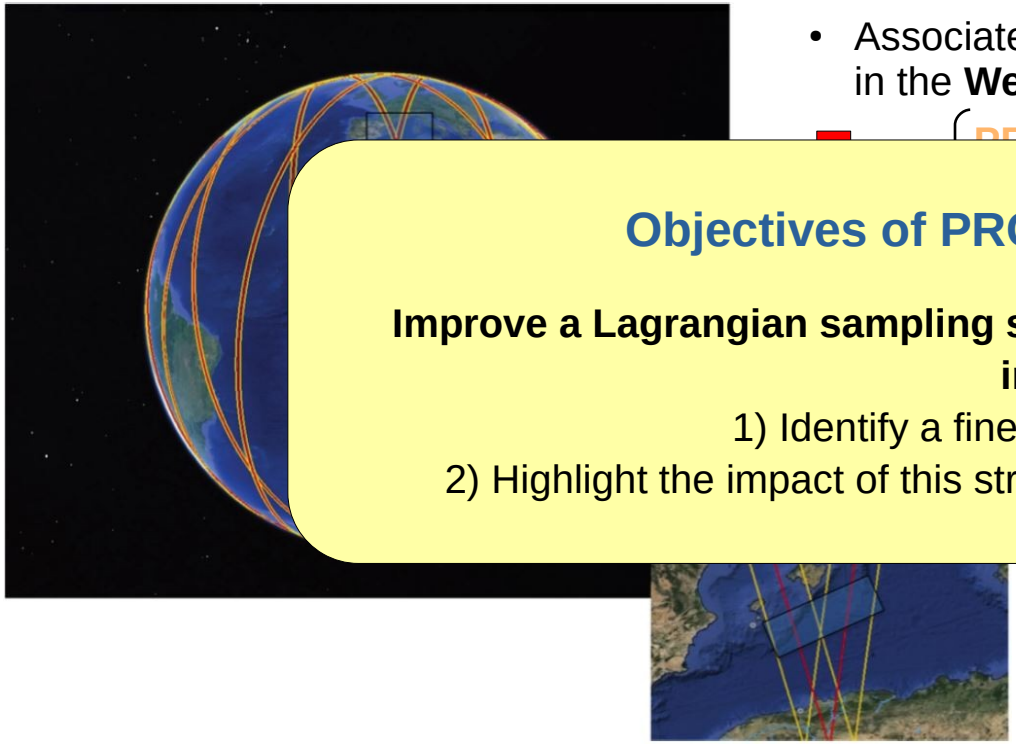
- Associated **cruises** in the area of **SWOT's crossover** in the **Western Mediterranean Sea** :

Objectives of PROTEVSMED-SWOT 2018 :

Improve a Lagrangian sampling strategy before BIOSWOT mission in 2022, in order to :

1) Identify a fine scale structure of interest.

2) Highlight the impact of this structure on the distribution of phytoplankton.



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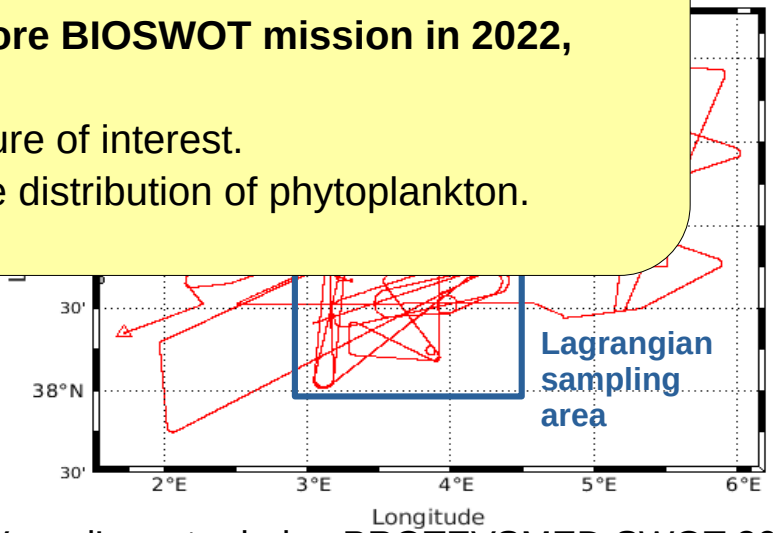


Vessel's route during PROTEVSMED SWOT 2018

2. Method : Adaptive and Lagrangian sampling strategy

- **Adaptive** (**SPASSO** "**S**oftware **P**ackage for an **A**daptive **S**atellite-based **S**ampling for **O**ceanographic cruises") :

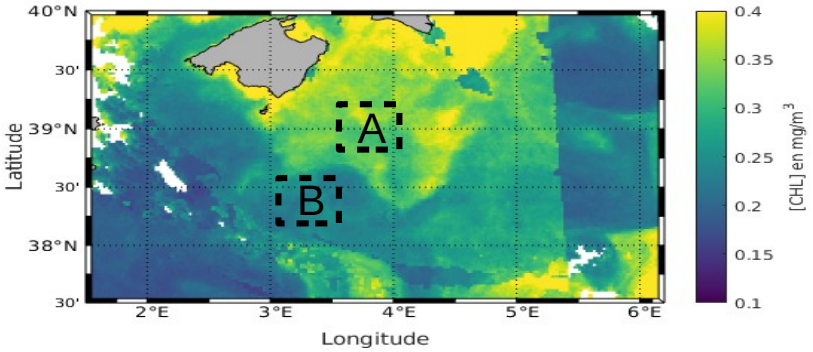
Automatic treatment of **model predictions and satellite data altimetry**, **ocean color**, and **surface temperature** in **Near Real Time (NRT)** and **Delayed Time (DT)**.

Lagrangian calculations : FSLE, advections of longitude and latitude, etc.

Daily bulletin to **guide** the in situ sampling strategy as well as the interpretation of collected observations.

→ Identification of **2 types of water A and B in surface**, characterized by their **chlorophyll concentration**.

*Visit the site **www.spasso.mio.osupytheas.fr** to download SPASSO user guide (pdf) and SPASSO package.*

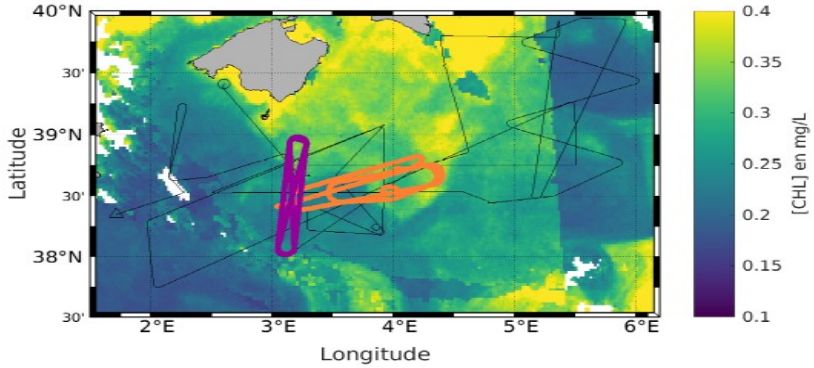


- **Lagrangian :**

Travel of the ship across the different types of water A and B.

"**Hippodrome West-East**" : 8 - 10 May 2018.

"**Hippodrome North-South**" : 11 - 12 May 2018.



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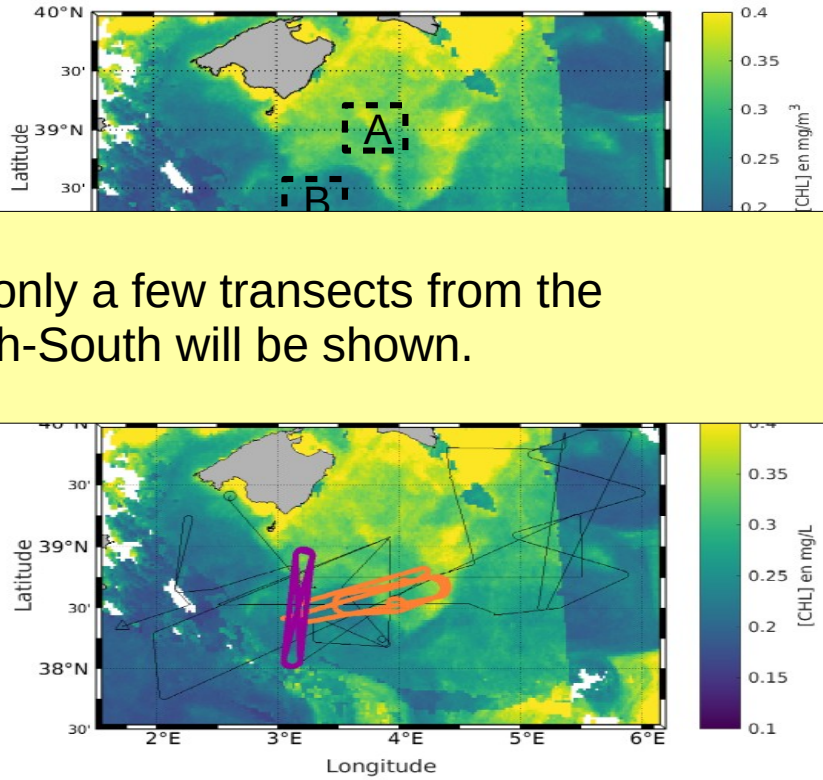


In the following slides, only a few transects from the hippodrome North-South will be shown.

- **Lagrangian :**

Travel of the ship across the different types of water A and B.

"**Hippodrome West-East**" : 8 - 10 May 2018.

"**Hippodrome North-South**" : 11 - 12 May 2018.

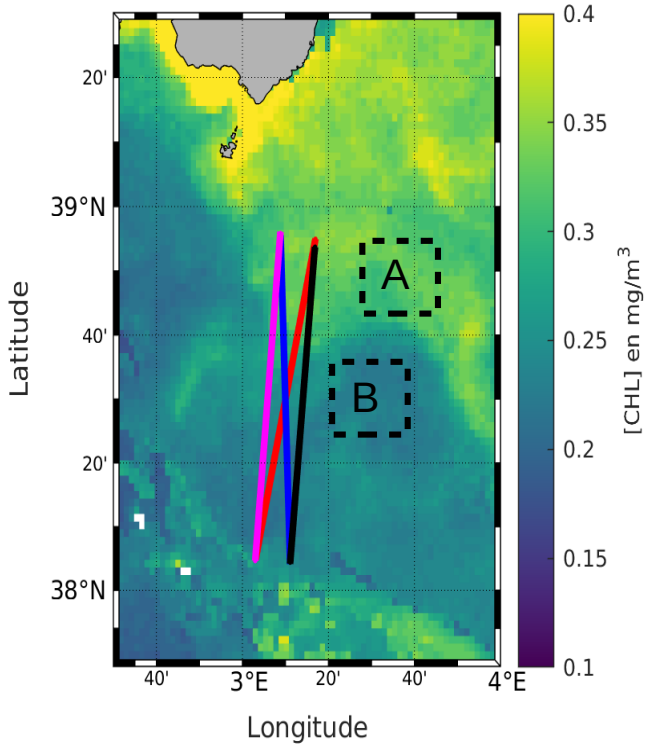
2. Method : Adaptive and Lagrangian sampling strategy

- **Sampling at high frequency :**

Multidisciplinary in situ sensors (ADCP, TSG, Seasoar and **an automated flow cytometer)** have been used to sample at **high spatial resolution physical** and **biological variables**.

The **temporal sampling** in water masses **A** and **B** has been adapted to the **biological time scales**, in order to reconstruct the **phytoplankton diurnal cycle**.

Transect 1 : 11 May 2:10 am – 8:37 am
Transect 2 : 11 May 9:58 am – 4:40 pm
Transect 3 : 11 May 6:05 pm – 12 May 00:45 am
Transect 4 : 12 May 2:05 am – 8:20 am

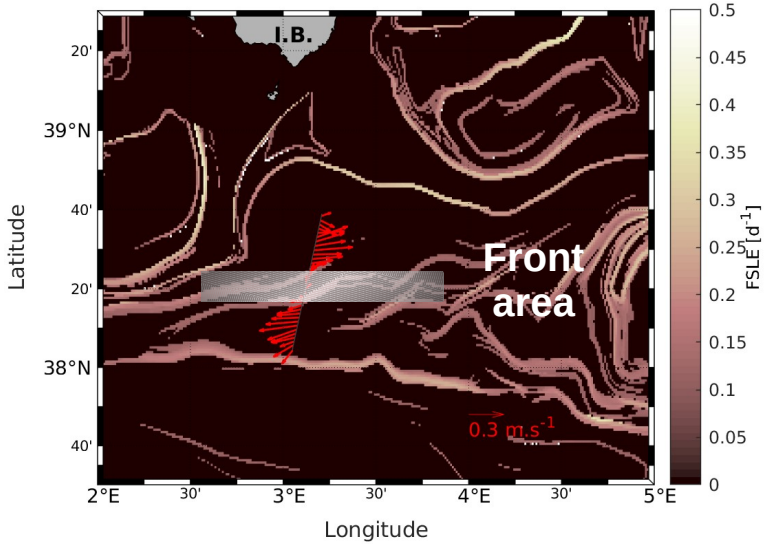


Transects of the hippodrome North-South

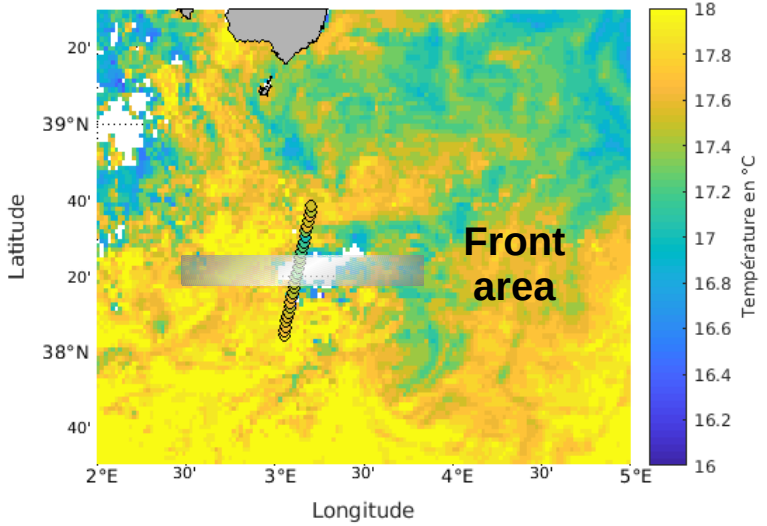
3. Results : Identification of a fine scale structure of interest

- Identification of a **front** area with a **correlation** between **physical results** in surface :

  Horizontal velocities sampled by Acoustic Doppler Current Profiler (ADCP)
  Temperature sampled by Thermosalinograph (TSG)
  Sea Surface Temperature (SST) and FSLE from satellite observations (d'Ovidio et al., 2004)

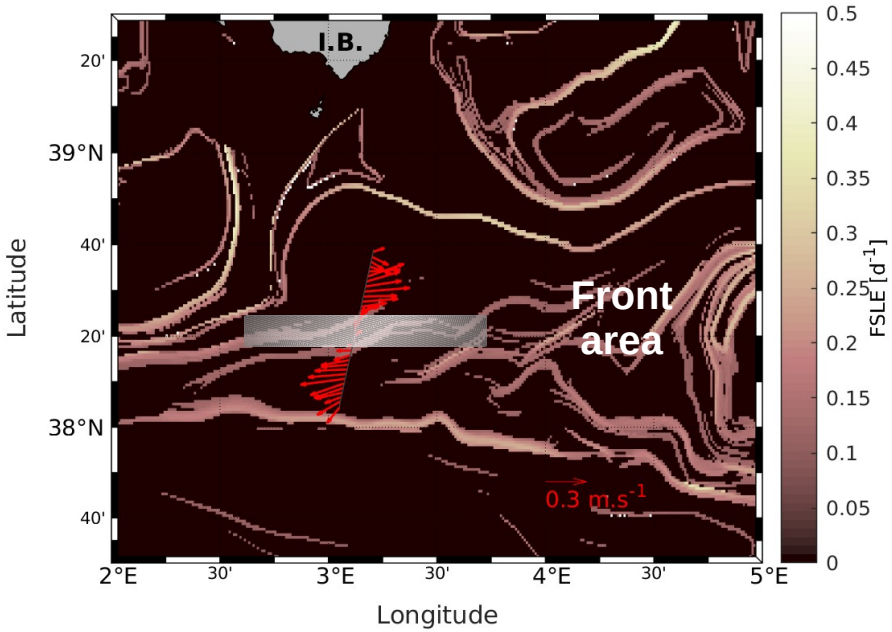


Map of horizontal velocities sampled by ADCP, with FSLE

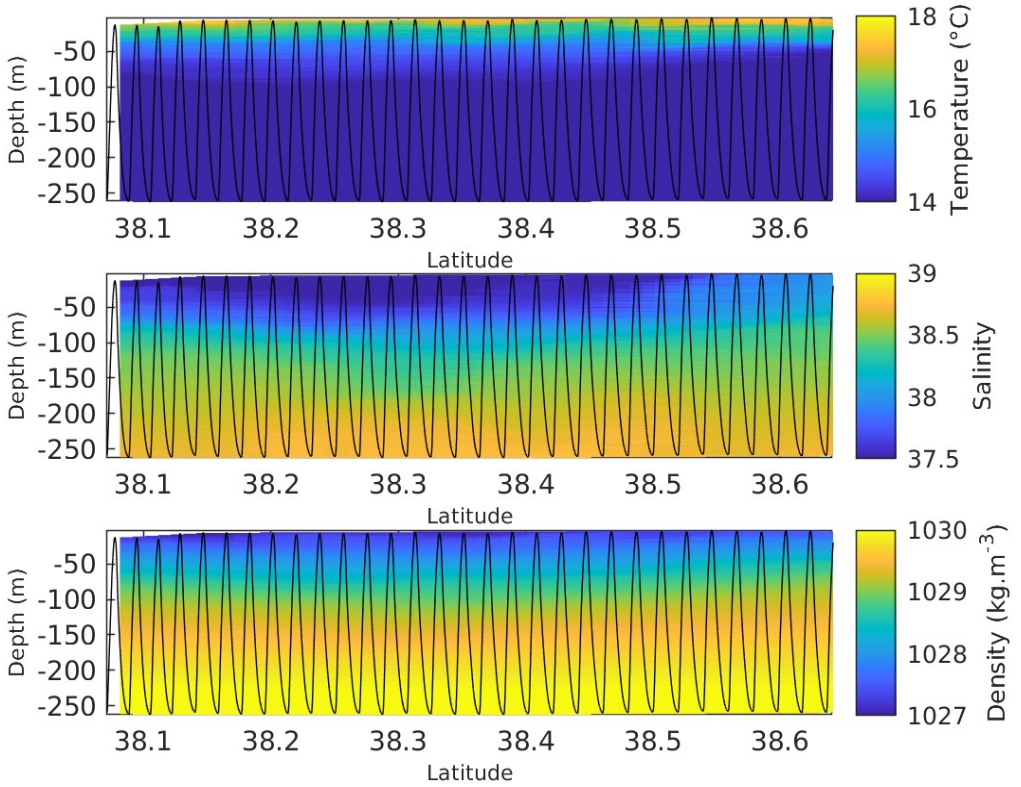


Map of temperature sampled by TSG, with SST

3. Results : Stratification in the front area



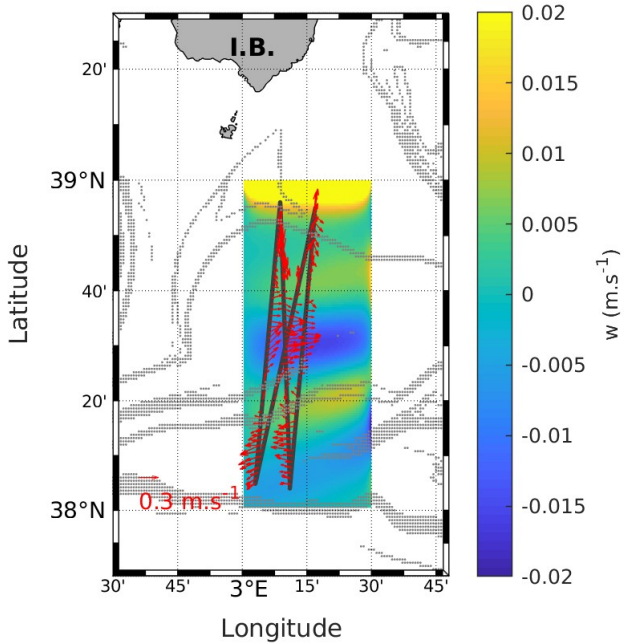
Map of horizontal velocities sampled by ADCP, with FSLE



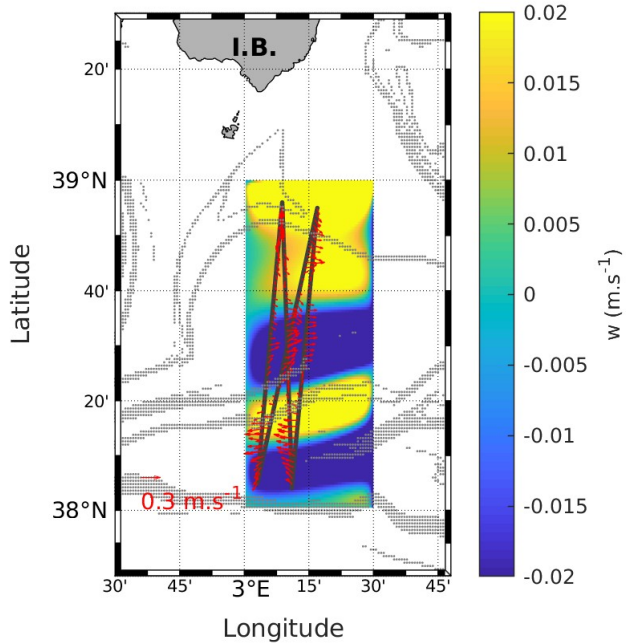
Deep sections of temperature, salinity and density sampled by Seasoar

3. Results : Vertical velocities in the front area

- Estimation of **vertical velocities** in the **front** area with the method of the Q vector (Hoskin et al., 1978) :



Vertical velocities at 25 m



Vertical velocities at 85 m

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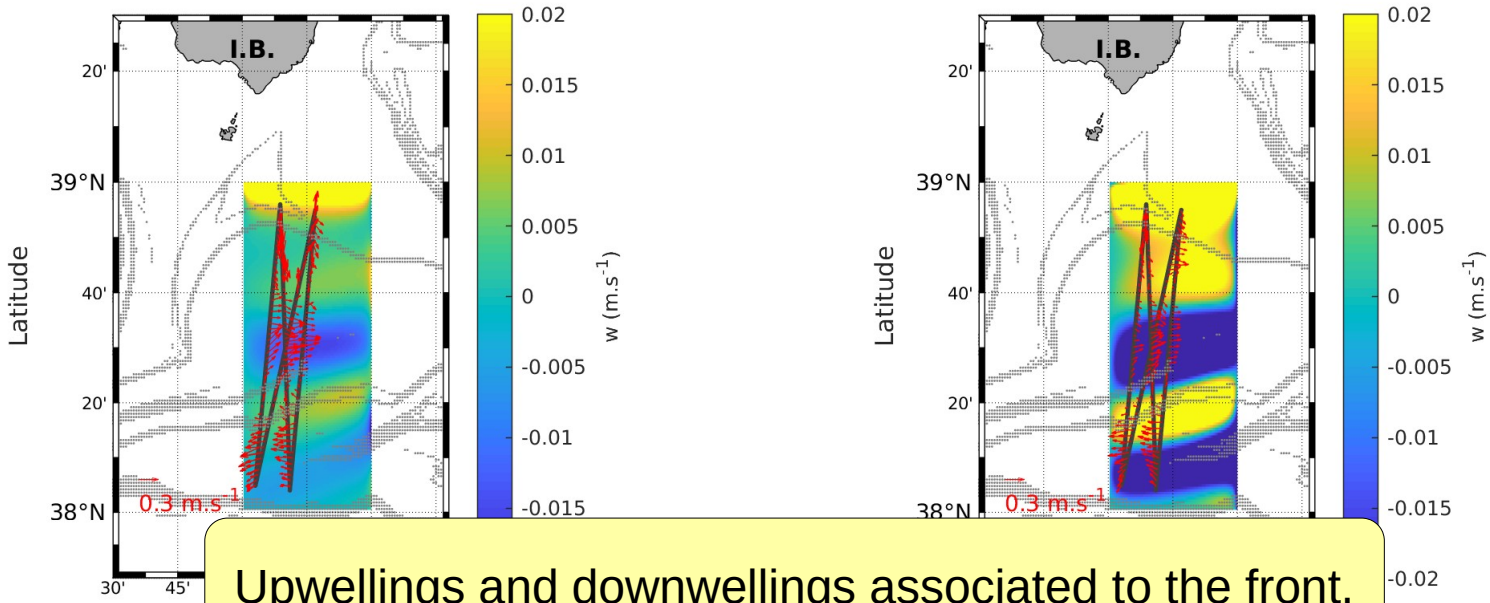


Upwellings and downwellings associated to the front.

Vertical velocities at 25 m

Vertical velocities at 85 m

3. Results : Identification of types of water

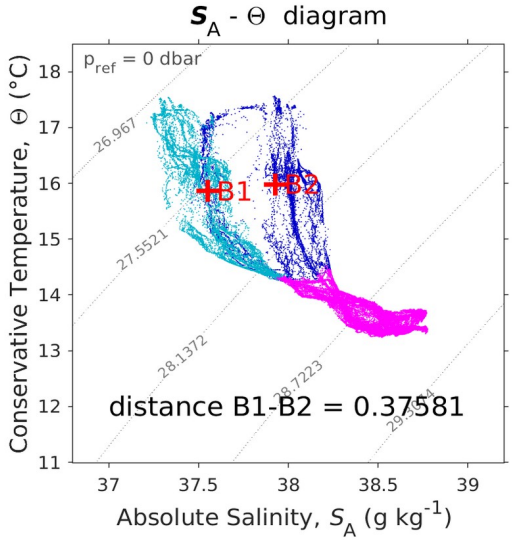
- An **iterative method** to **separate** types of water **in surface (separation between 28.6 of density ~ 0 – 80 m)** :

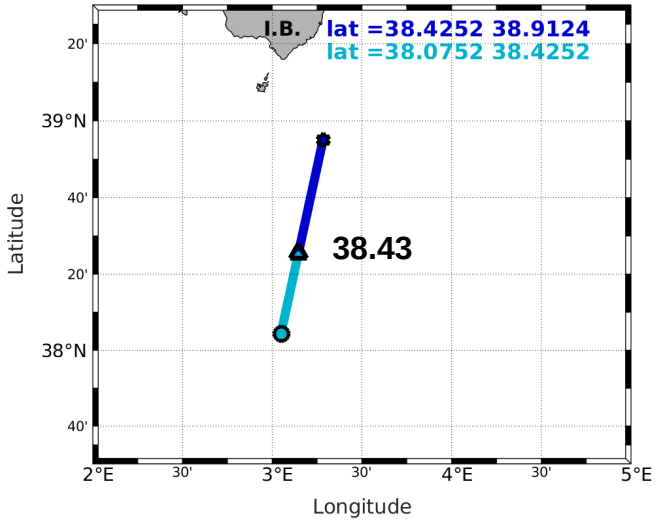
Selection of temperature (T) and salinity (S) along each transect, **every 0.1 degrees of latitude**.

Calculation of the **barycenters B1 = (S1, T1)** and **B2 = (S2, T2)** along each transect, every 0.1 degrees of latitude.

With $S1=\frac{1}{n}\sum_{i=1}^{n} S1_i$ and $T1=\frac{1}{n}\sum_{i=1}^{n} T1_i$; $S2=\frac{1}{n}\sum_{i=1}^{n} S2_i$ and $T2=\frac{1}{n}\sum_{i=1}^{n} T2_i$

Calculation of the distance : B1 - B2 = | S1 - S2 | .





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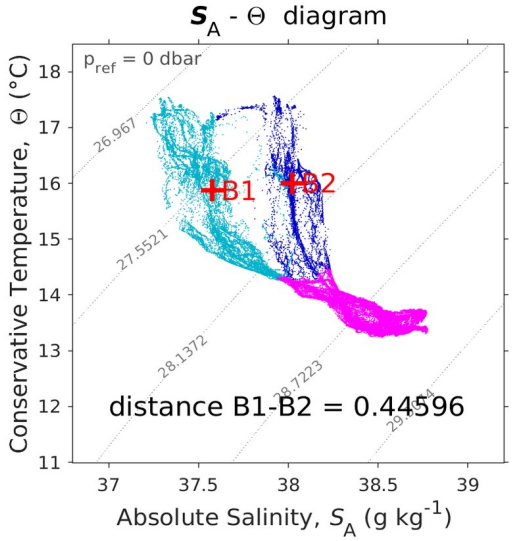

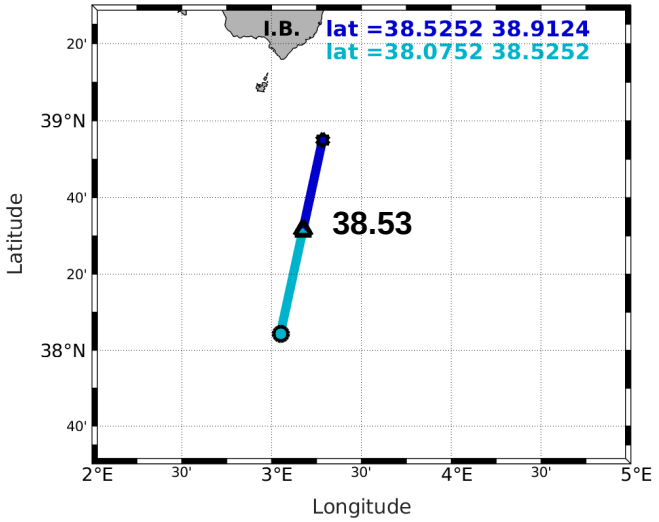

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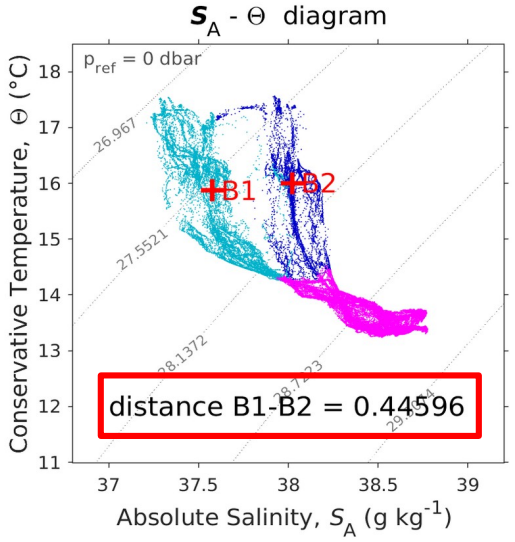
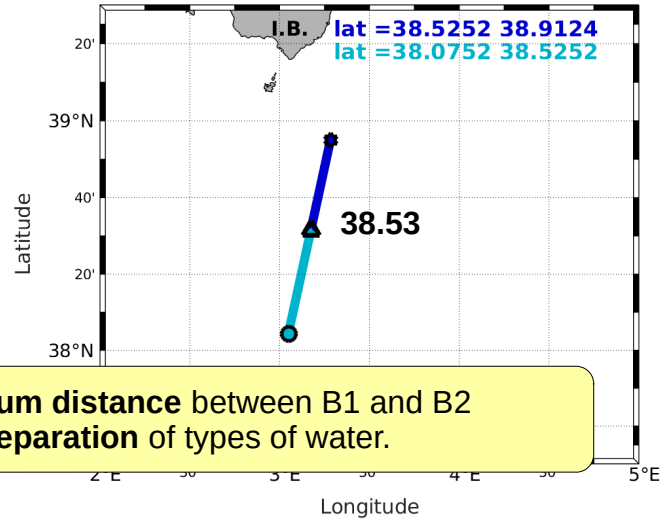


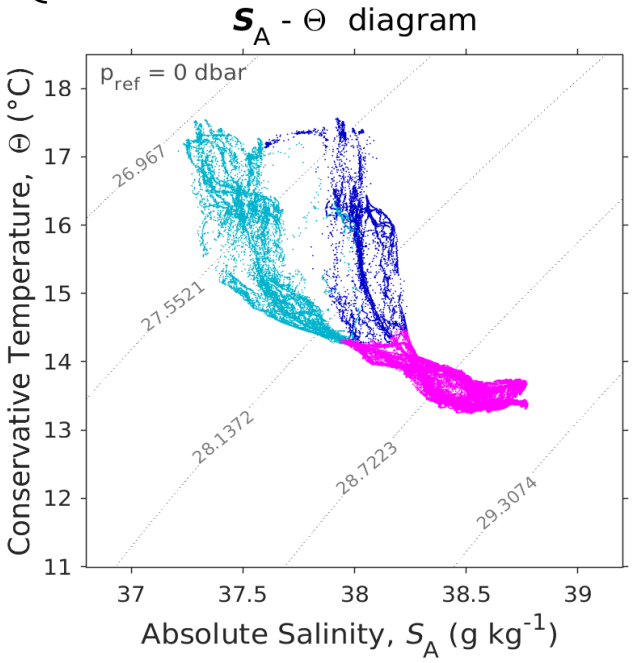


Selection of the **maximum distance** between B1 and B2 to find the **best separation** of types of water.

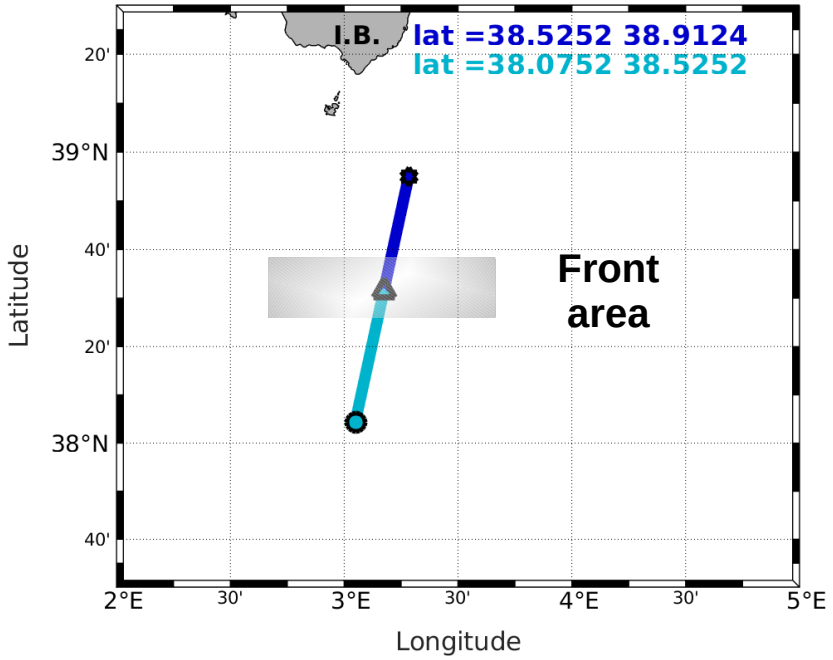
3. Results : Identification of types of water

- **Diagram temperature salinity :**

2 Atlantic Water (AW) in surface : **AW recent** and **AW old**
Intermediate Water (IW) in depth



- **Separation between AW recent and AW old in the front area :**



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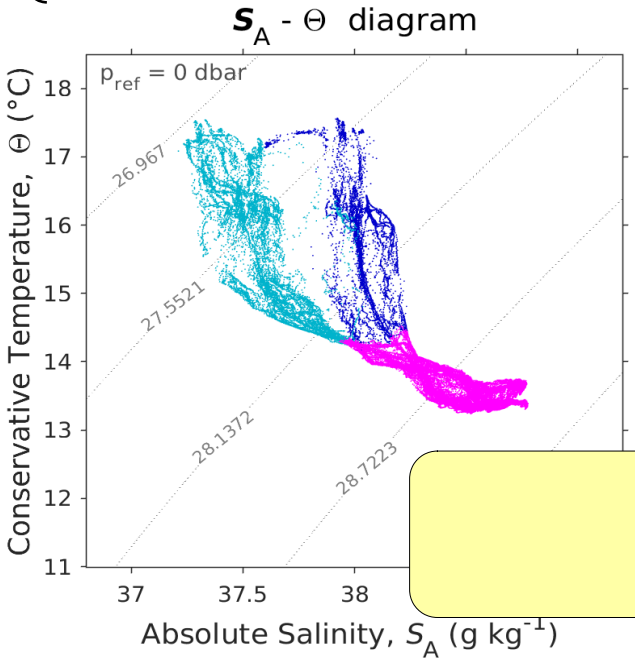

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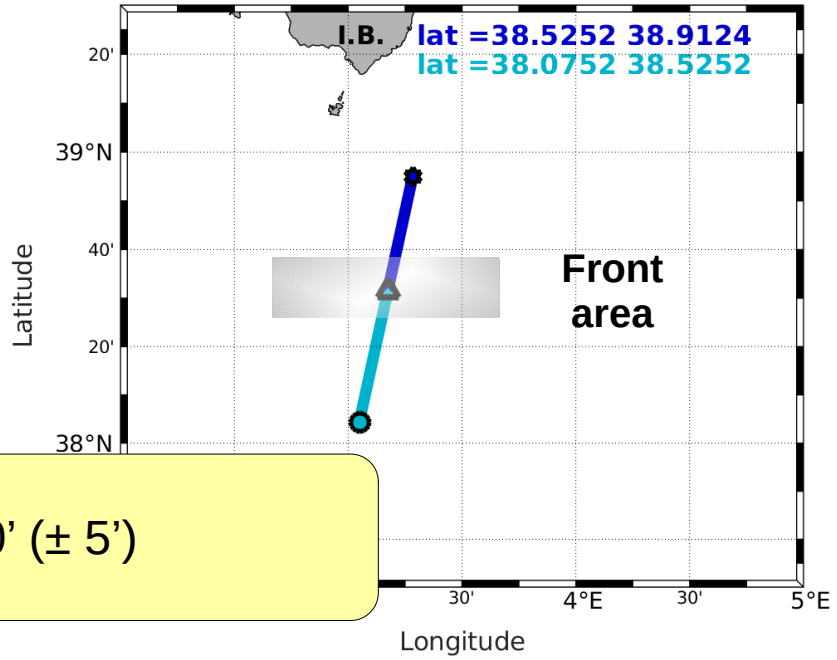

Front ~ 38°N 30’ (± 5’)

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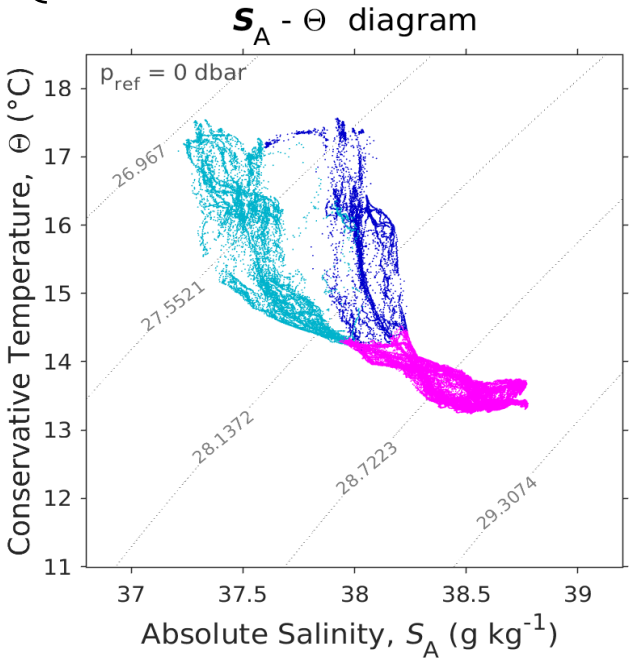
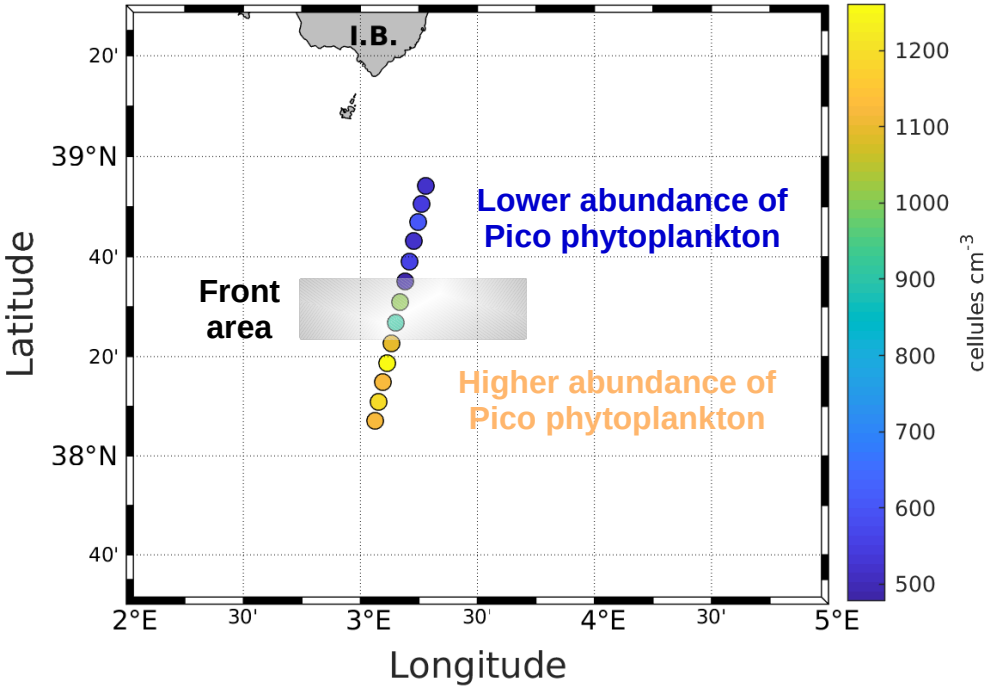
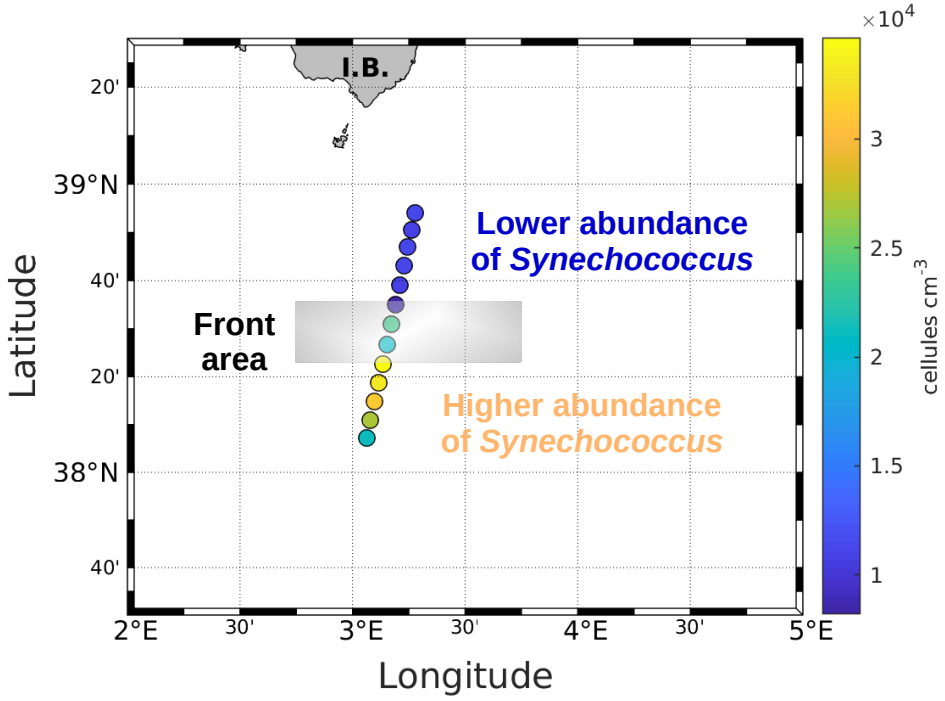


	AW recent	AW old	IW
Depth	0-80 m	0-80 m	> 80 m
Temperature	15-27.6°C	15-27.6°C	< 13.5 °C
Salinity	36.5-38	38-38.5	~ 38.5

3. Results : Distribution of phytoplankton abundance



Abundance of Pico phytoplankton



Abundance of *Synechococcus*

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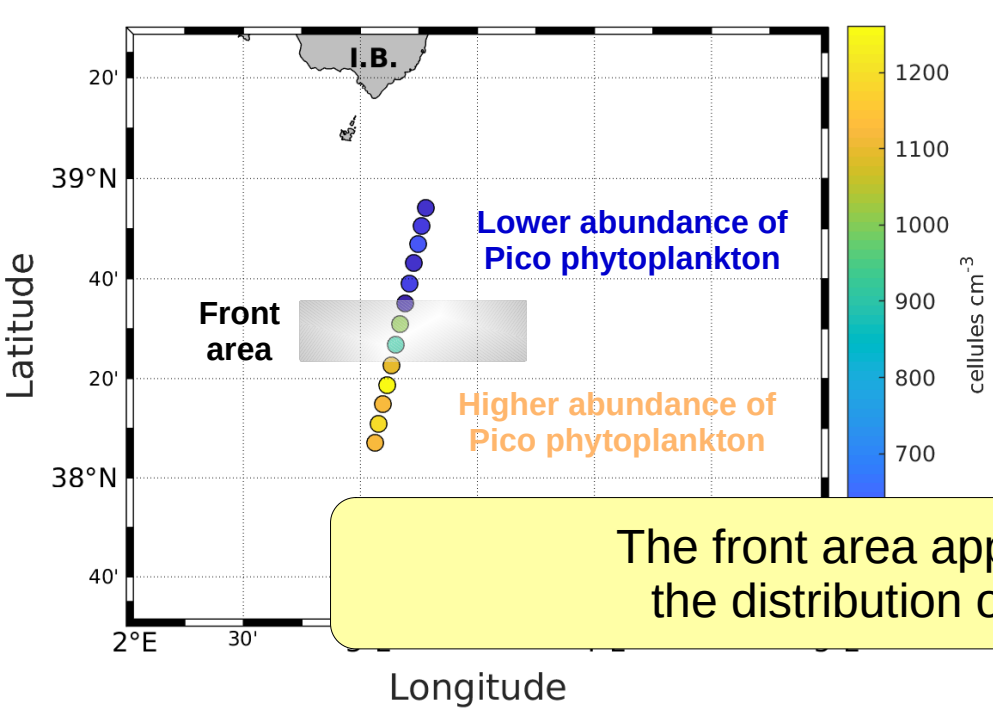
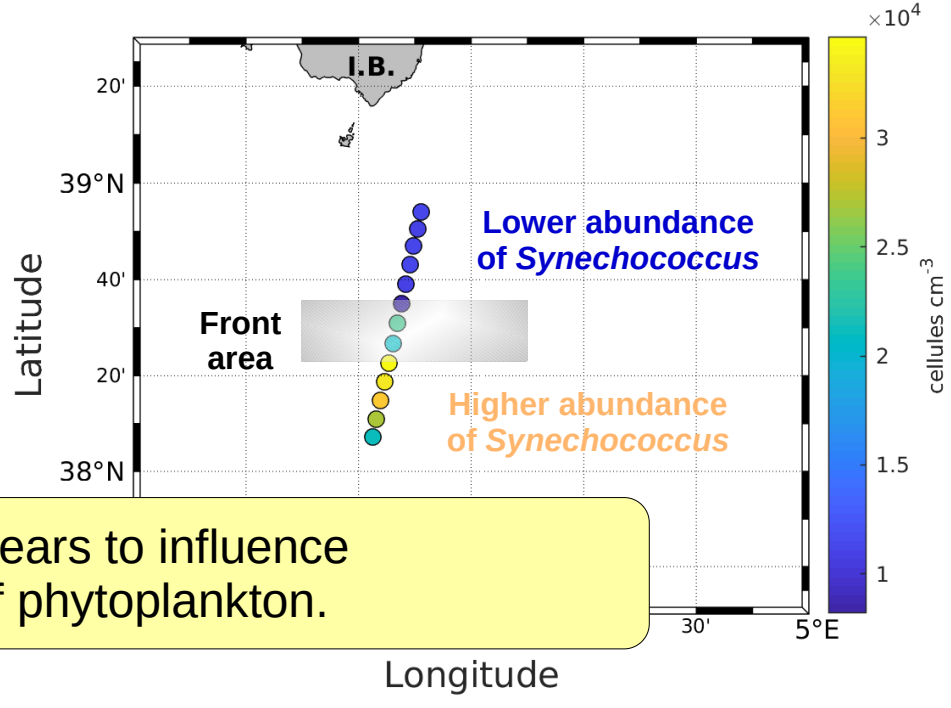


Abundance of Pico phytoplankton



Abundance of *Synechococcus*

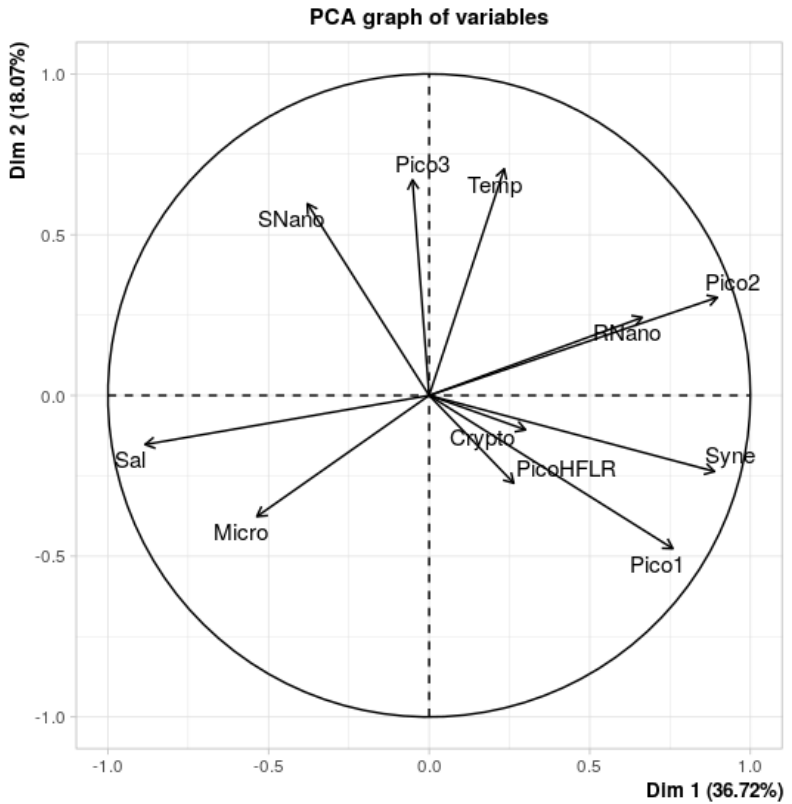
The front area appears to influence the distribution of phytoplankton.

3. Results : Statistical analysis for biology

- **Principal component analysis (PCA) :**

  Classification of 11 variables :

  → Salinity
  → Temperature
  → Abundances of the different types of phytoplankton (Micro, Pico, Synechococcus, etc)



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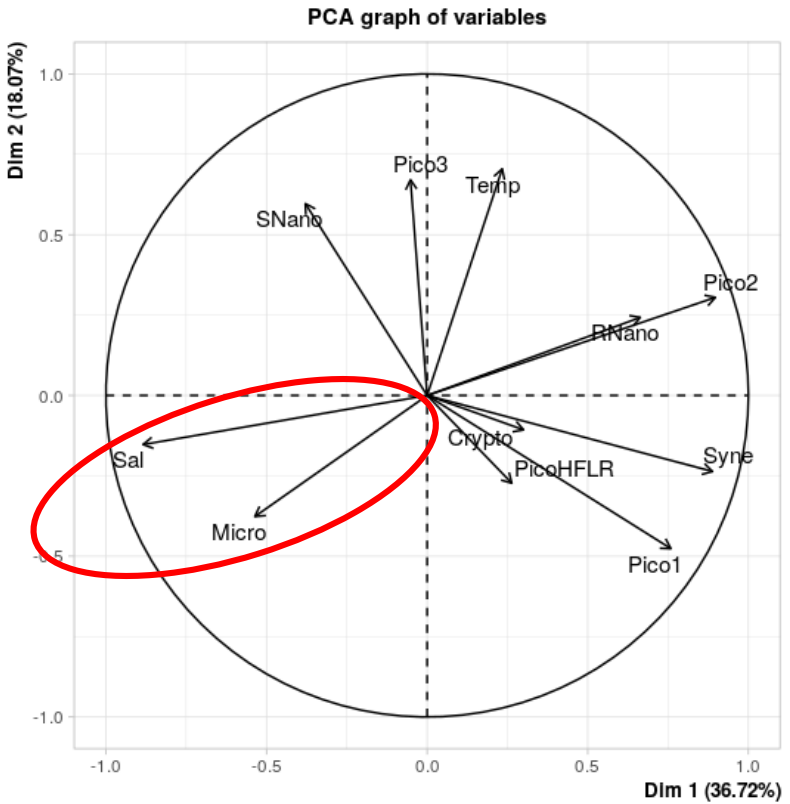
Identification of 3 groups :

Group 1 : Salinity (Sal) and Micro Phytoplankton (Micro)



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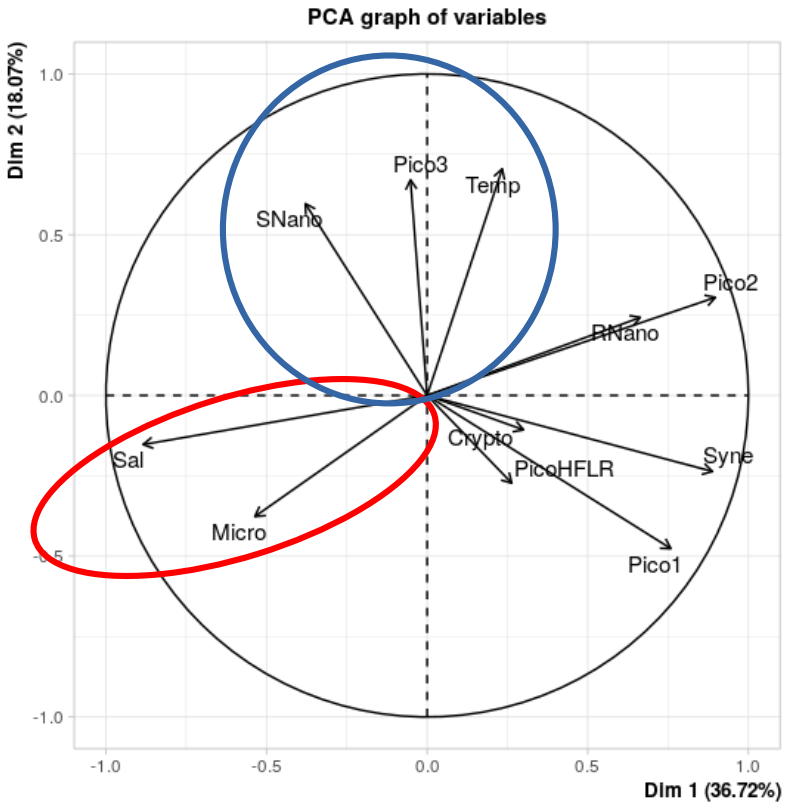
Group 1 : Salinity (Sal) and Micro Phytoplankton (Micro)
Group 2 : Temperature (Temp), Pico Phytoplankton (Pico3), Nano Phytoplankton (Snano)



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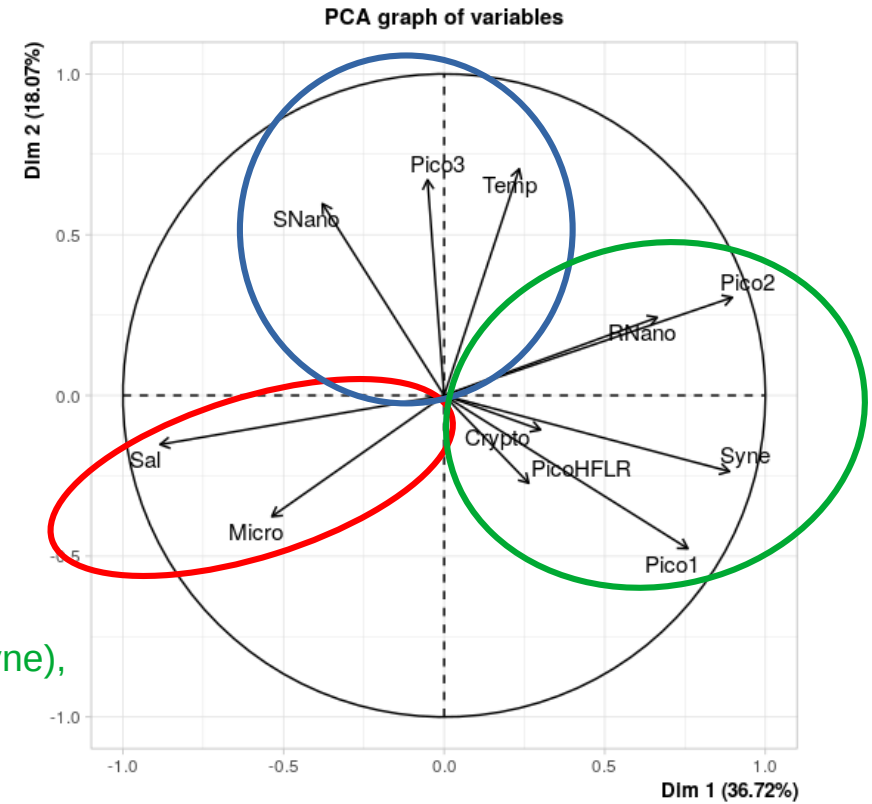
→ Abundances of the different types of phytoplankton (Micro, Pico, Synechococcus, etc)

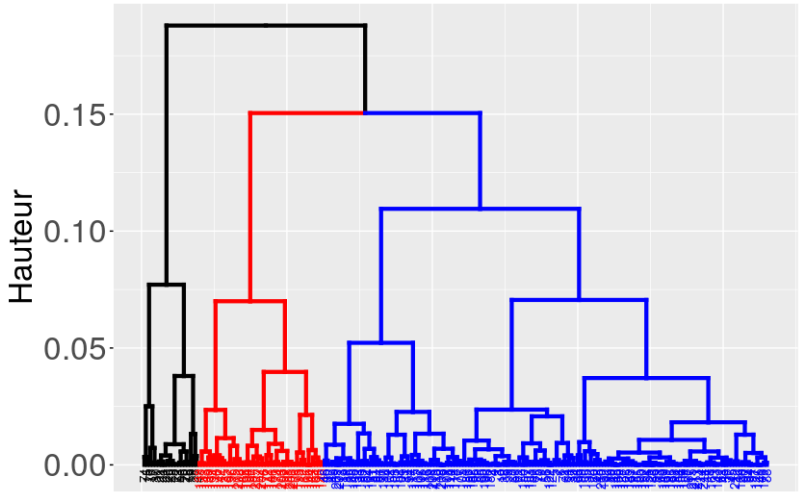
Identification of 3 groups :

Group 1 : Salinity (Sal) and Micro Phytoplankton (Micro)
Group 2 : Temperature (Temp), Pico Phytoplankton (Pico3), Nano Phytoplankton (Snano)
Group 3 : Pico Phytoplankton (Pico1 & 2), *Synechococcus* (Syne), Nano Phytoplankton (RNano)

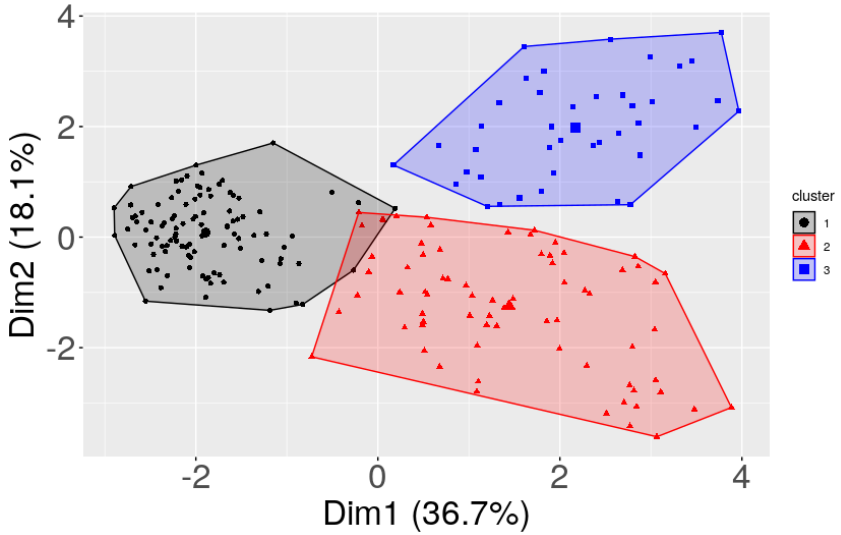


3. Results : Statistical analysis for biology

- **Ascending hierarchical classification (AHC) and with the K-medoid algorithm :**



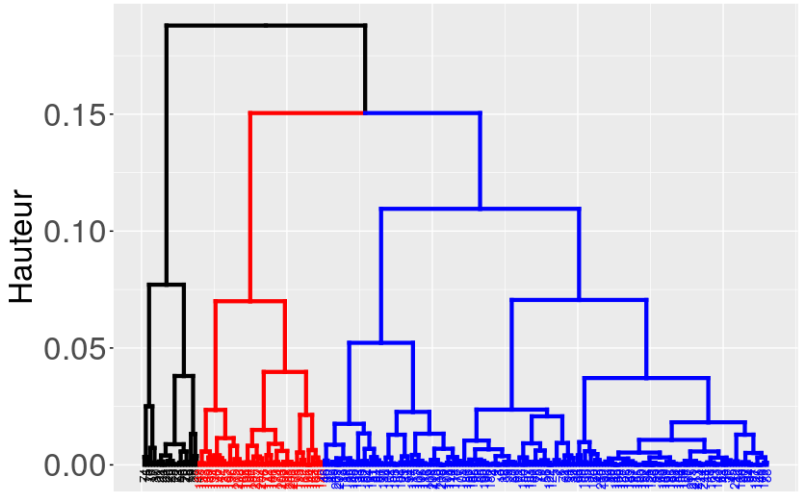
Ascending hierarchical classification

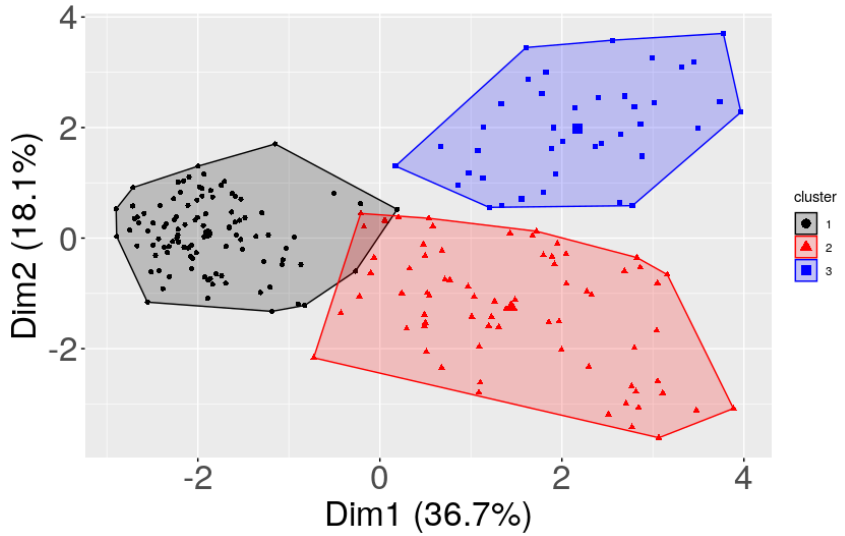


Classification with the K-medoid algorithm

3. Results : Statistical analysis for biology

- **Ascending hierarchical classification (AHC) and with the K-medoid algorithm :**

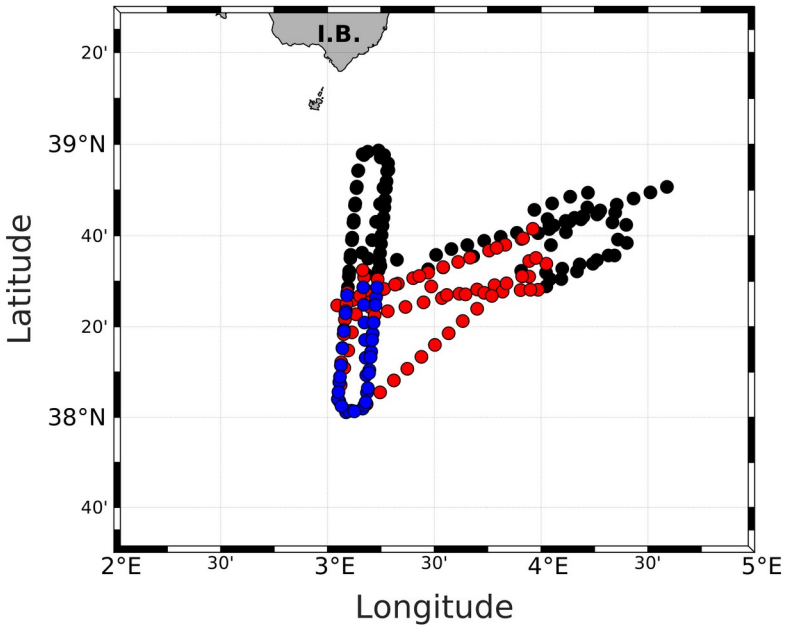


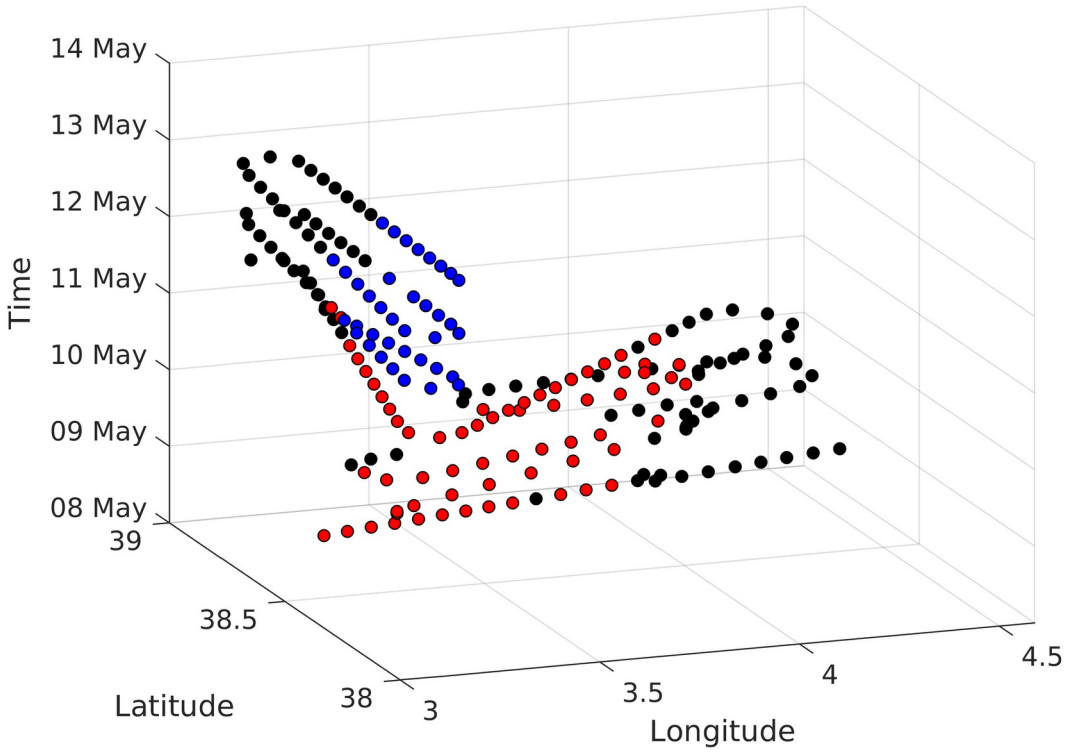


The 3 groups are also represented with these 2 other statistical analyzes.

3. Results : Statistical analysis for biology

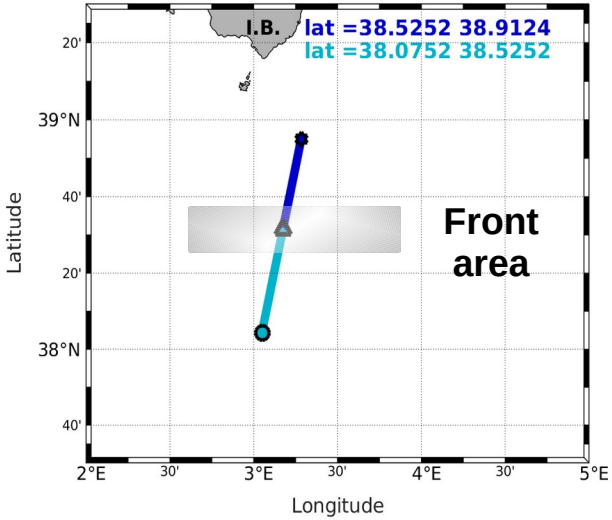
- **Localisation of the 3 groups :**



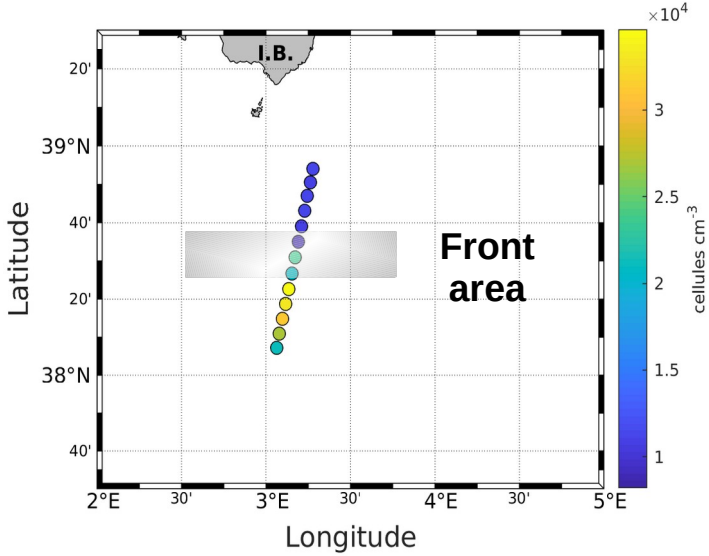


3. Results : Physical and biological coupling

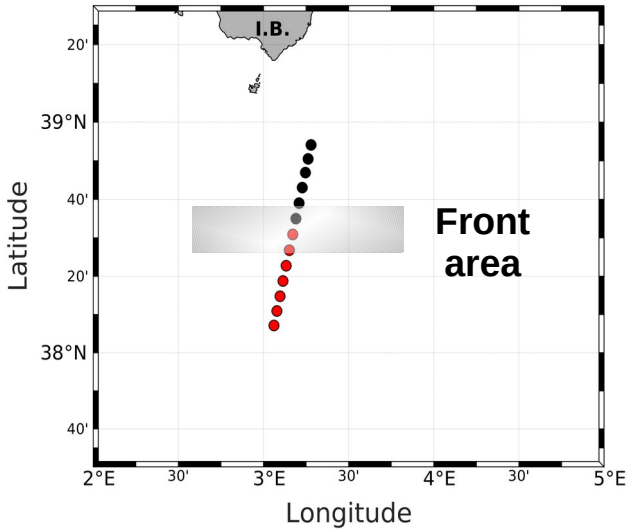
- **Correlation between the different results of the hippodrome North-South :**



Identification of the front area with diagram temperature - salinity



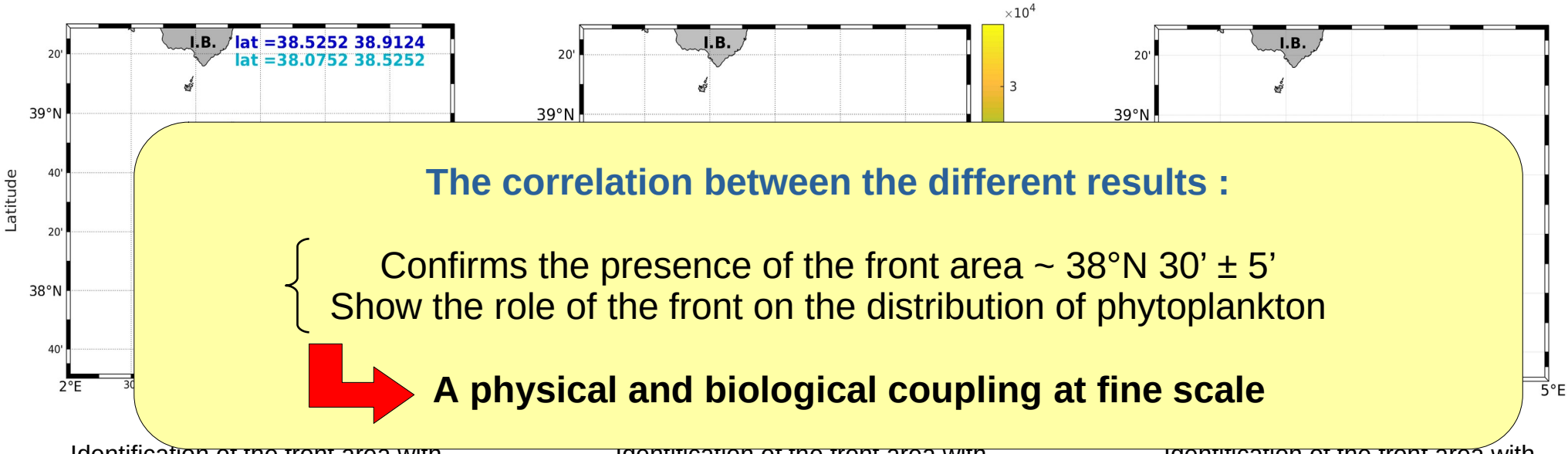
Identification of the front area with the abundance of *Synechococcus*



Identification of the front area with the groups from the statistical analysis

3. Results : Physical and biological coupling

- **Correlation between the different results of the hippodrome North-South :**



The correlation between the different results :

Confirms the presence of the front area ~ 38°N 30' ± 5'
Show the role of the front on the distribution of phytoplankton

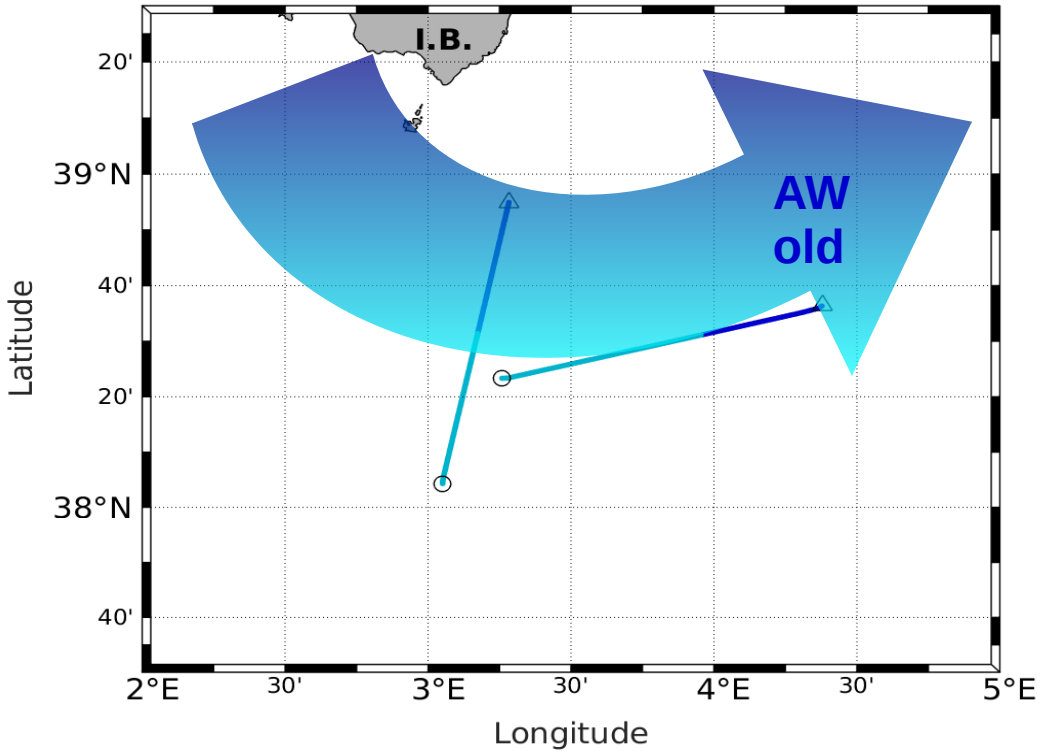
A physical and biological coupling at fine scale

Identification of the front area with diagram temperature - salinity

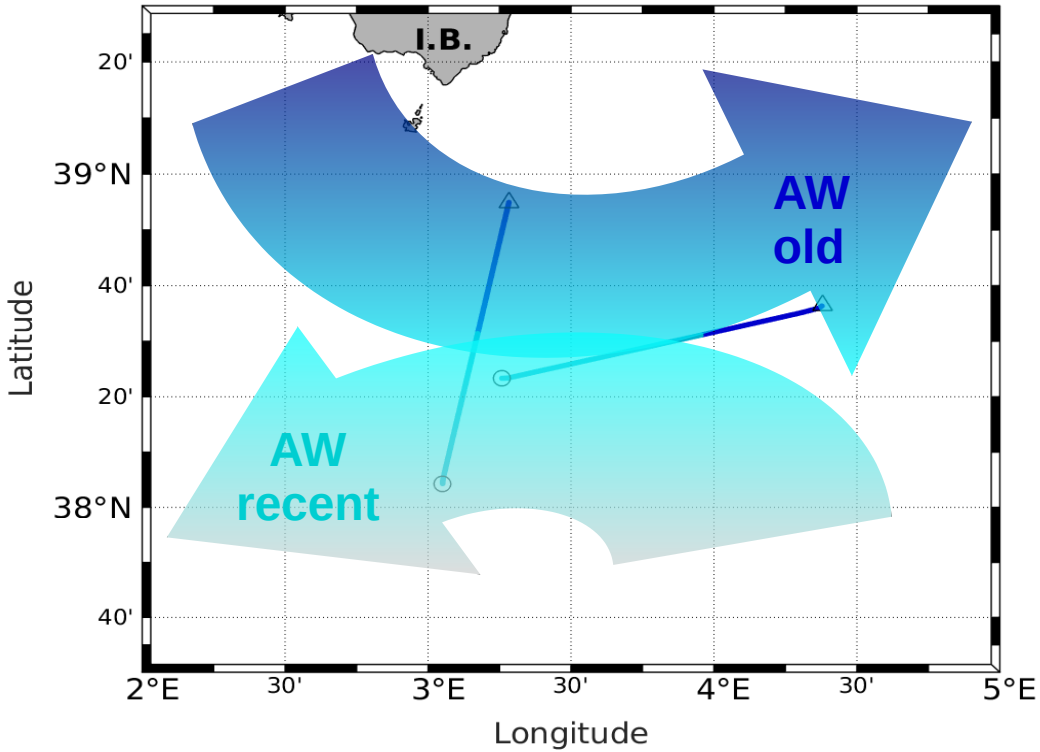
Identification of the front area with the abundance of *Synechococcus*

Identification of the front area with the groups from the statistical analysis

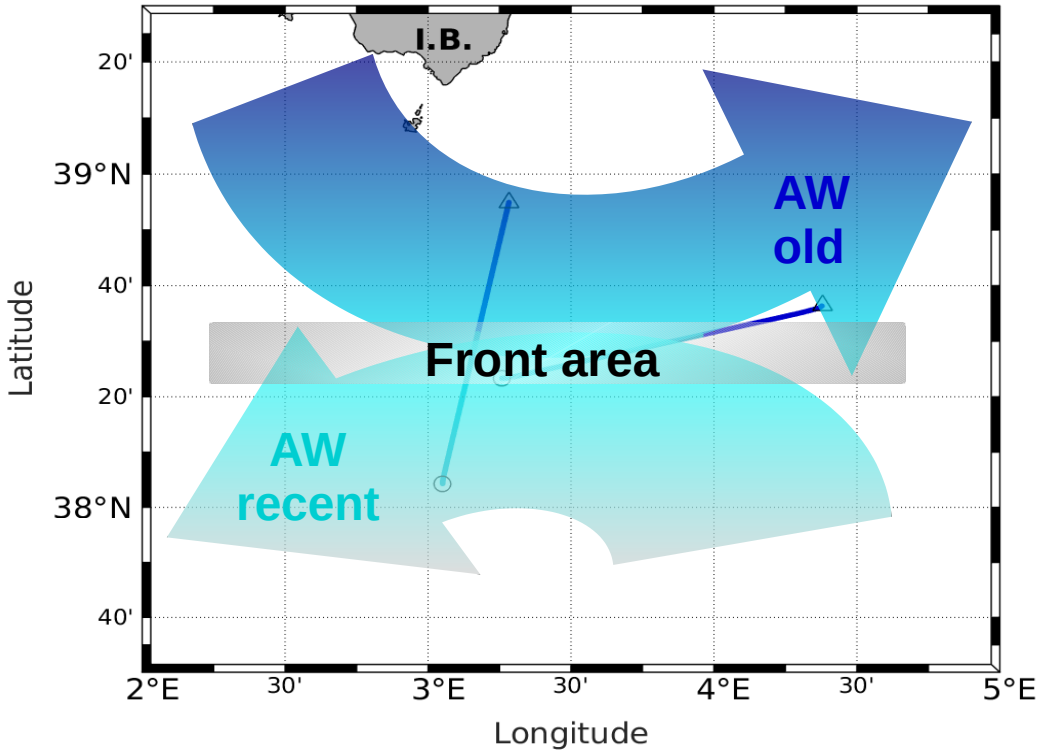
4. Scheme : Physical and biological coupling



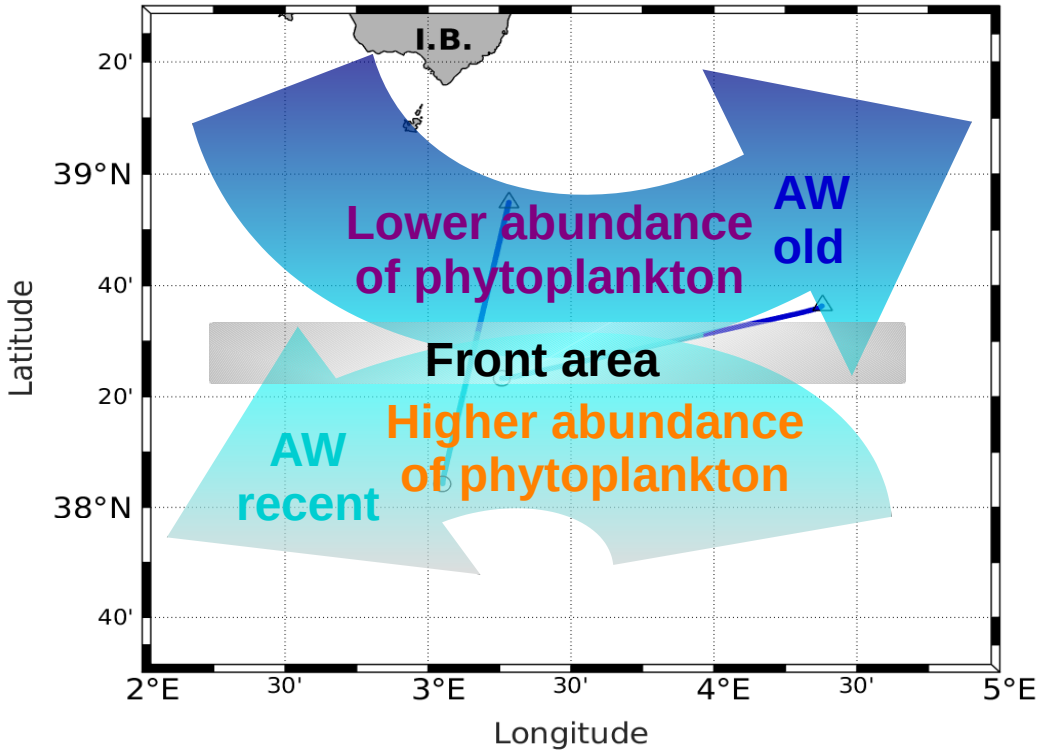
4. Scheme : Physical and biological coupling



4. Scheme : Physical and biological coupling



4. Scheme : Physical and biological coupling



5. Conclusion

- **Langragian sampling strategy** seems to be adapted for study the **fine scale structures**.
- The results of PROTEVSMED-SWOT show **coupling physics and biology** at fine scale.
- This SWOT's crossover area is an i**nteresting place** for study **fine scales** and their impacts on **biogeochemistry**.

Thanks for watching !

Questions ?

I will be avalaible in the text chat on Monday, 4 May 2020, 08:30–10:15.

6. Bibliography

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