



Centre d'études
biologiques de
Chizé

"Éléphants de Mer océanographes : contribution à l'observation des conditions physiques, biogéochimiques et biologiques de l'Océan Austral.

Christophe Guinet,

Baptiste Picard, Pauline Goulet, Didier Goulet-Tran, Marius Clabaux, Marius Molinet, Mathilde Chevallay, Yakov Uzan, Tiphaine Jeanniard du Dot,



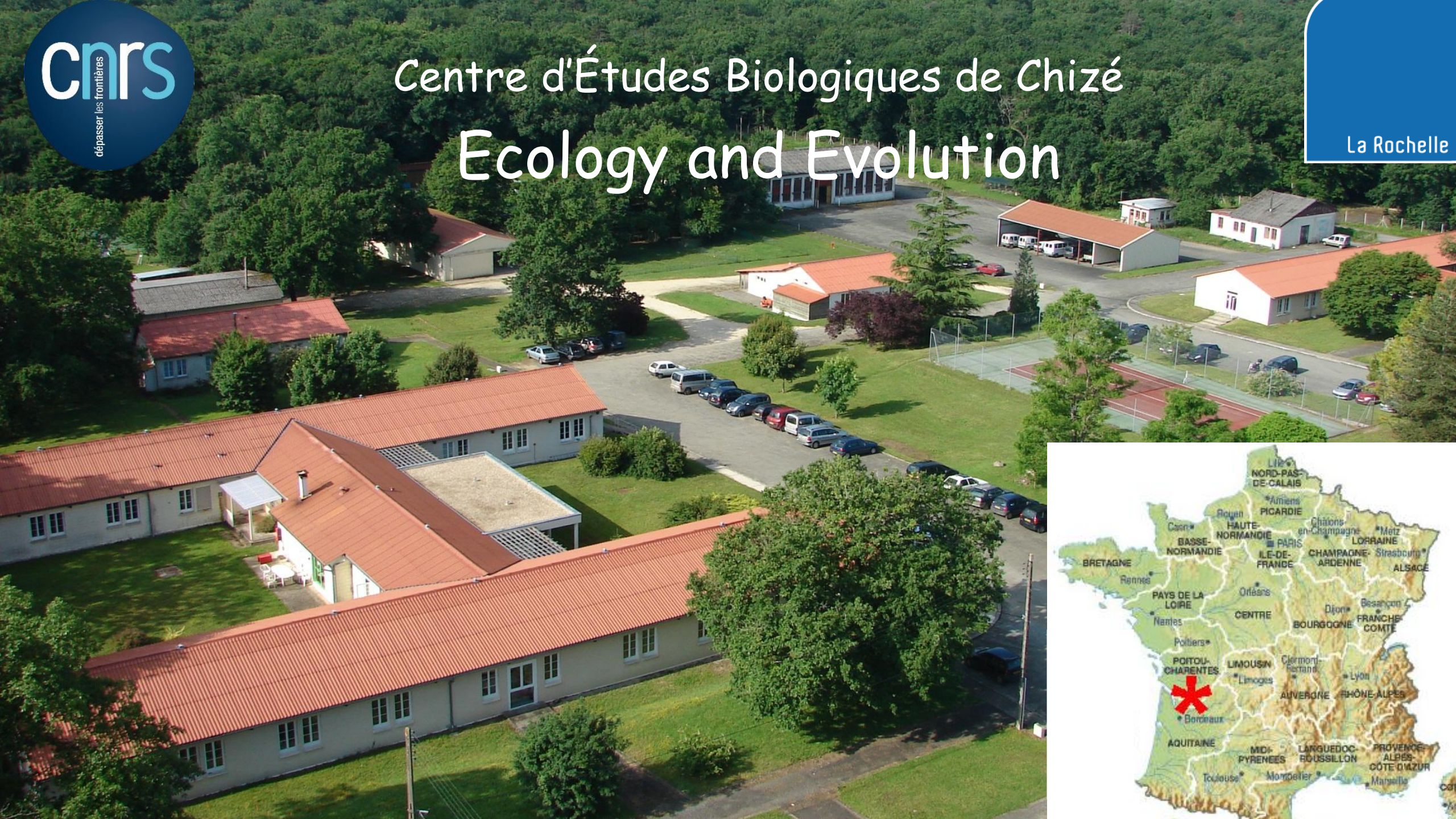
CENTRE NATIONAL D'ÉTUDES SPATIALES



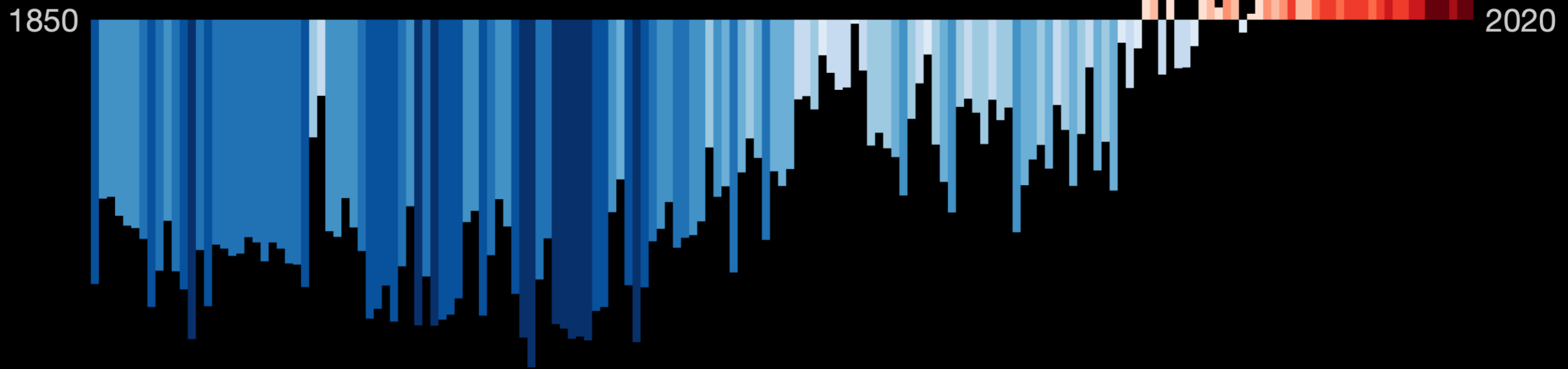
OASU 29 Sept. 2026

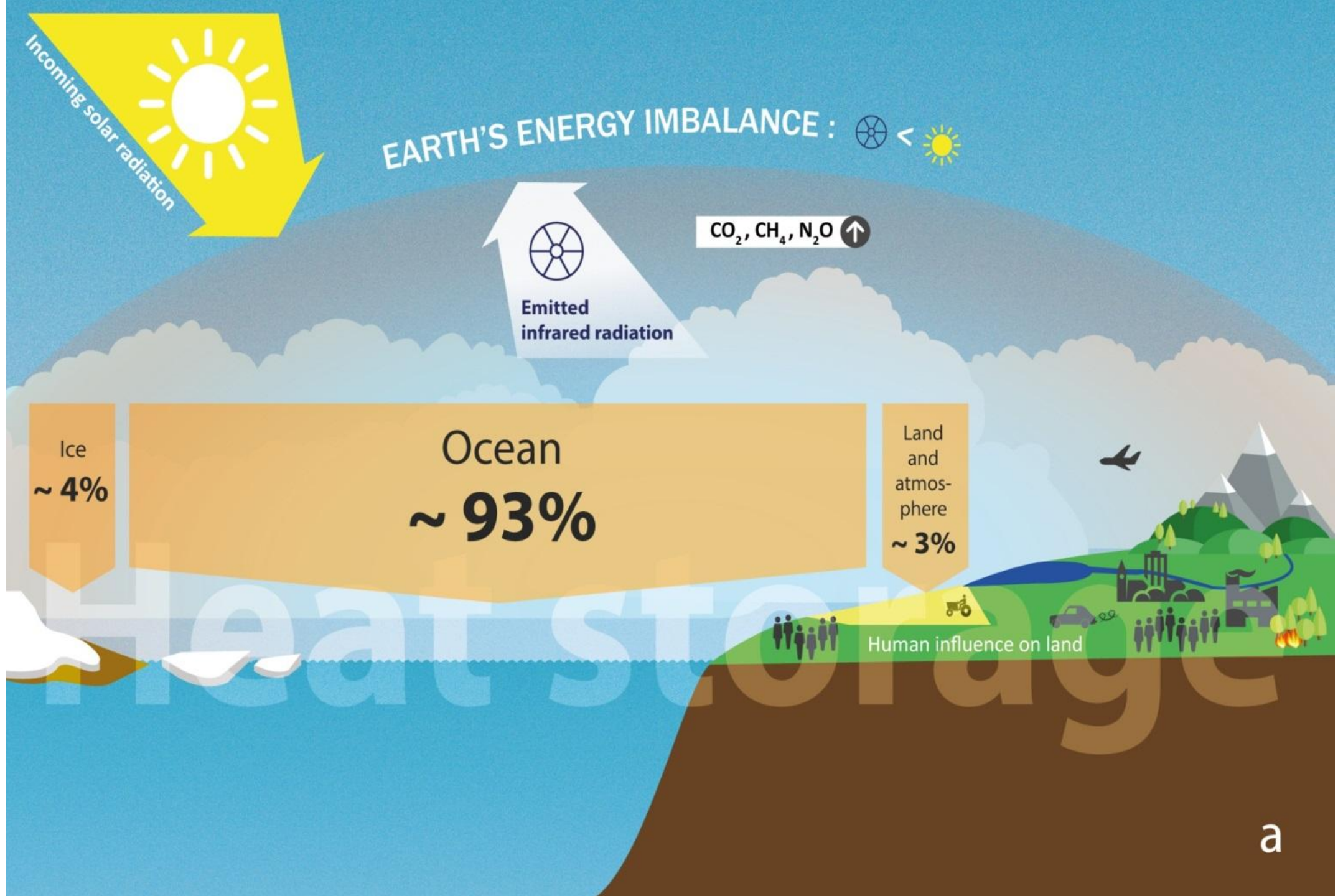
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Ecology and Evolution

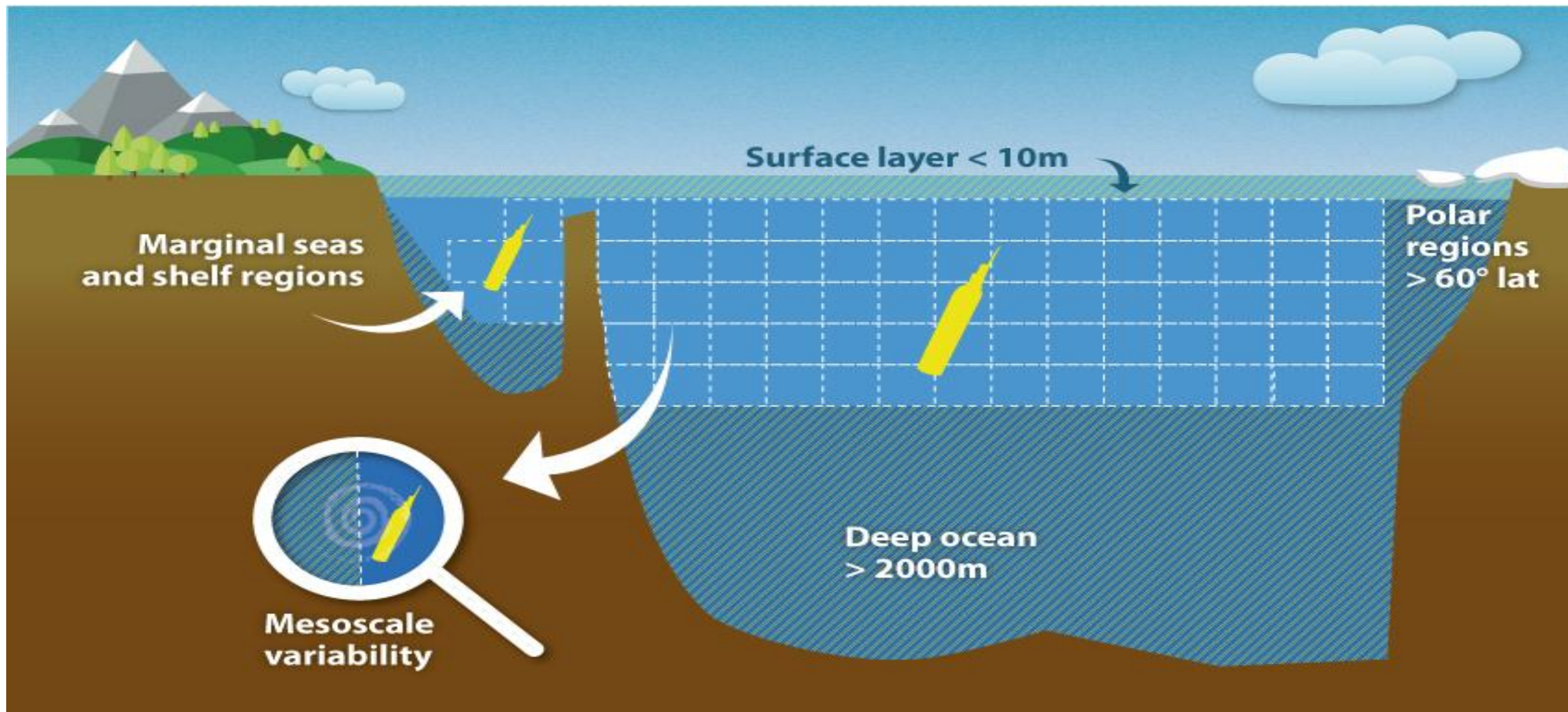


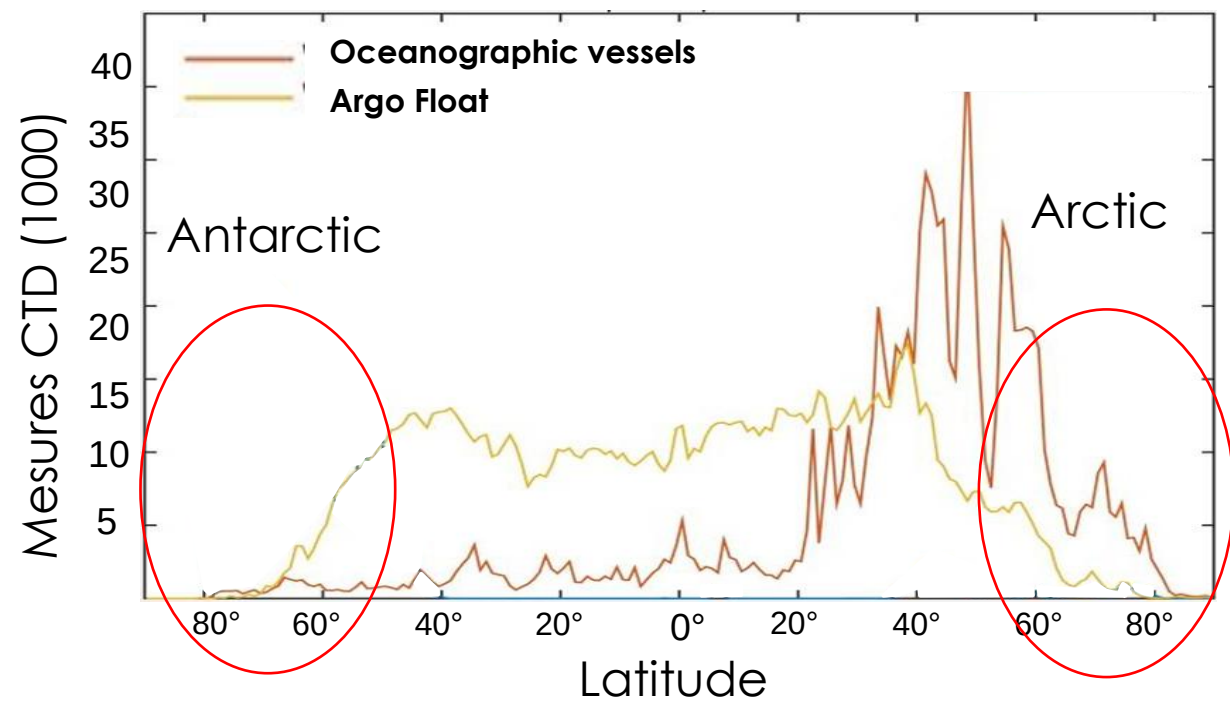
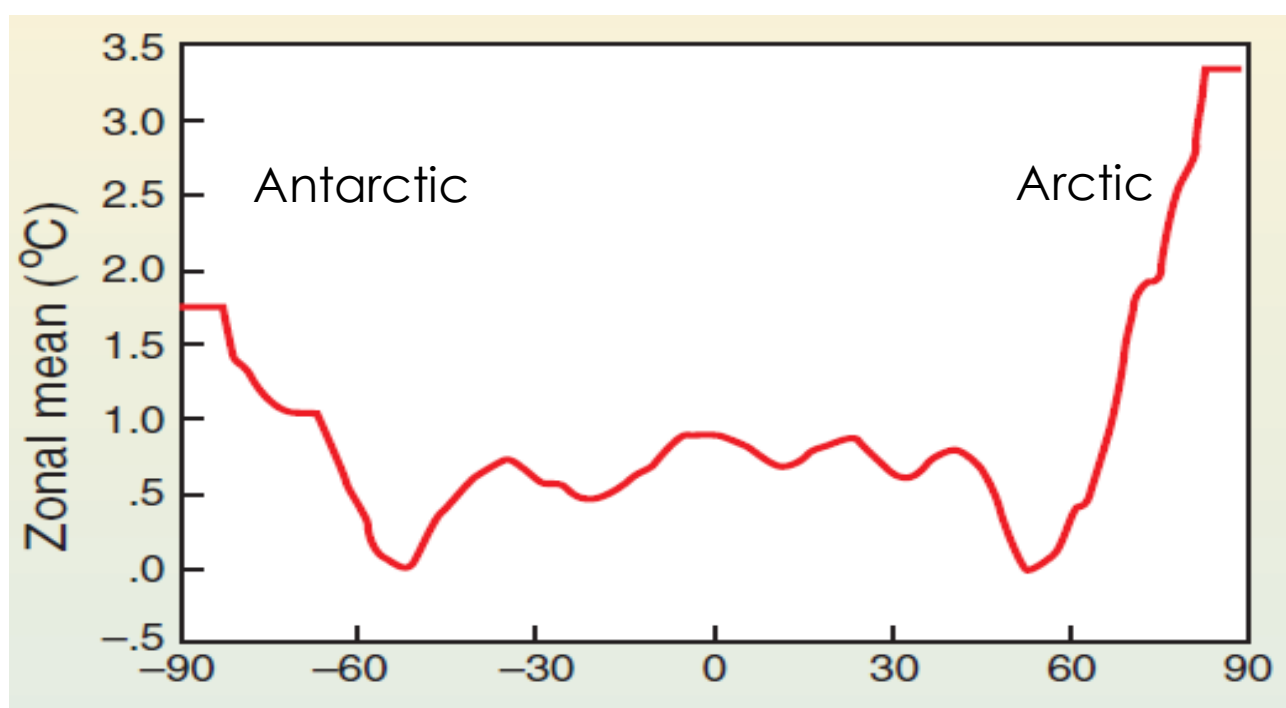
Global temperatures have increased by over 1.2°C





L'Océan Global: Des zones sous observées



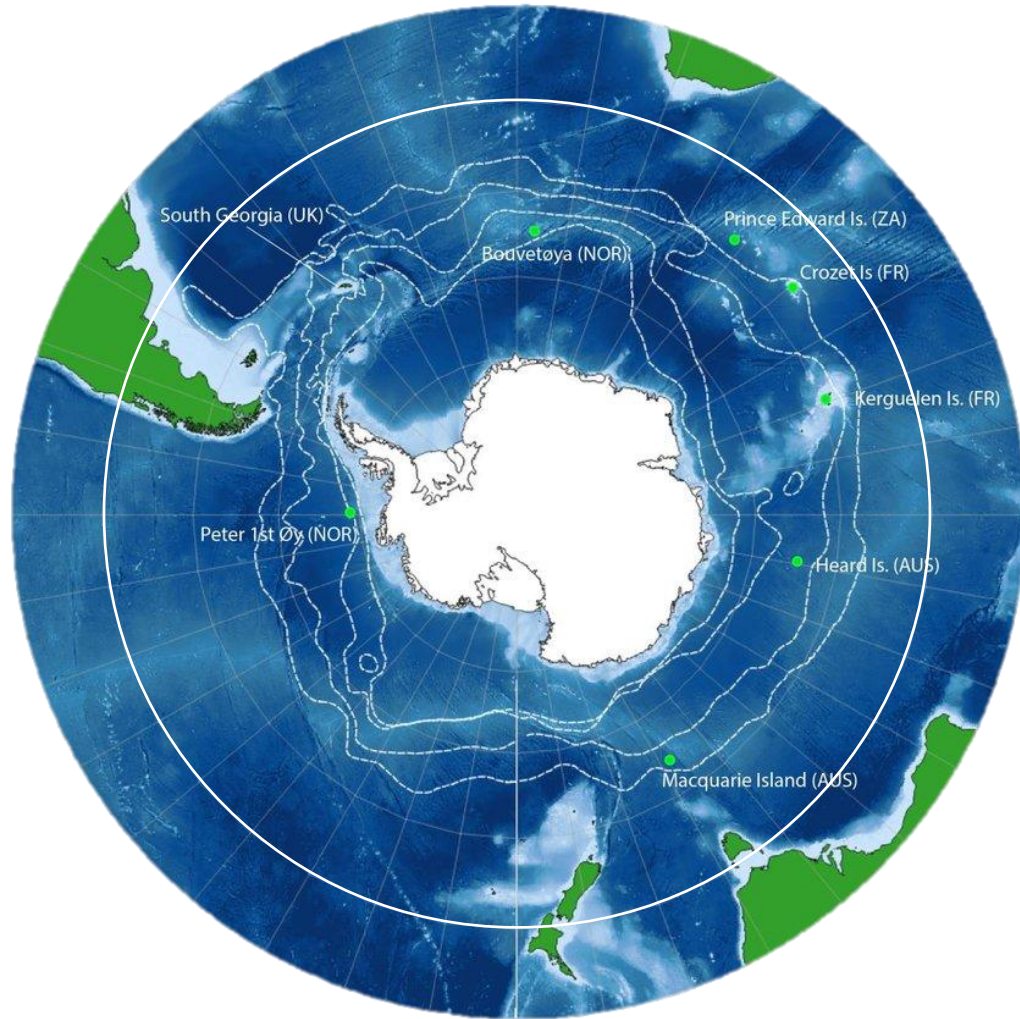


In a context of rapid environmental changes:

Marine animals are becoming new tools for:

- Observing changes in the physics and biology of the ocean
- Assessing the ecological consequences of these changes.

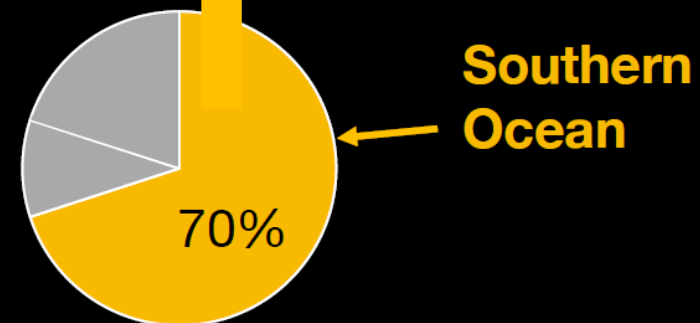
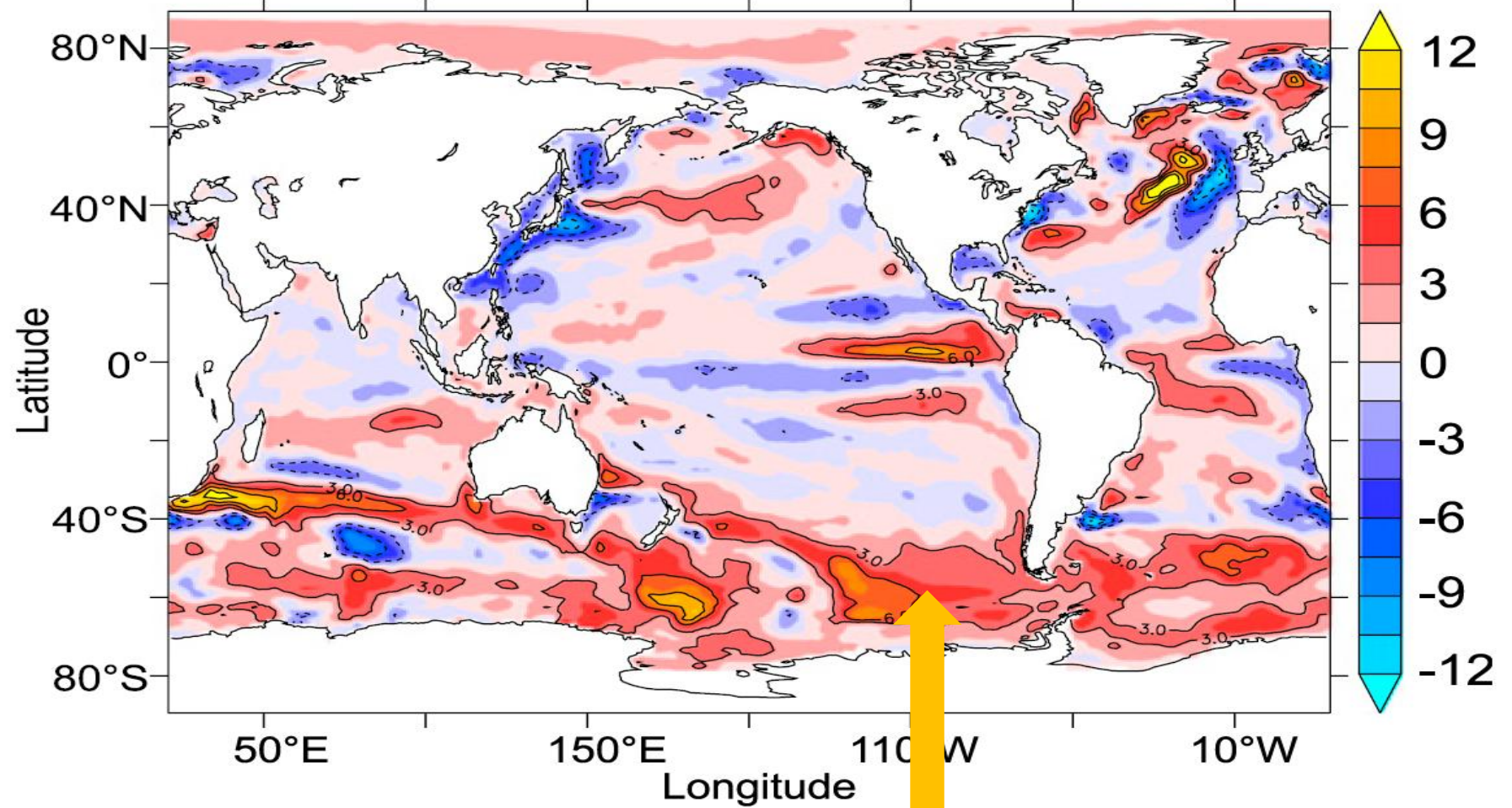
The Southern Ocean



Relative to the Global Ocean it represents :

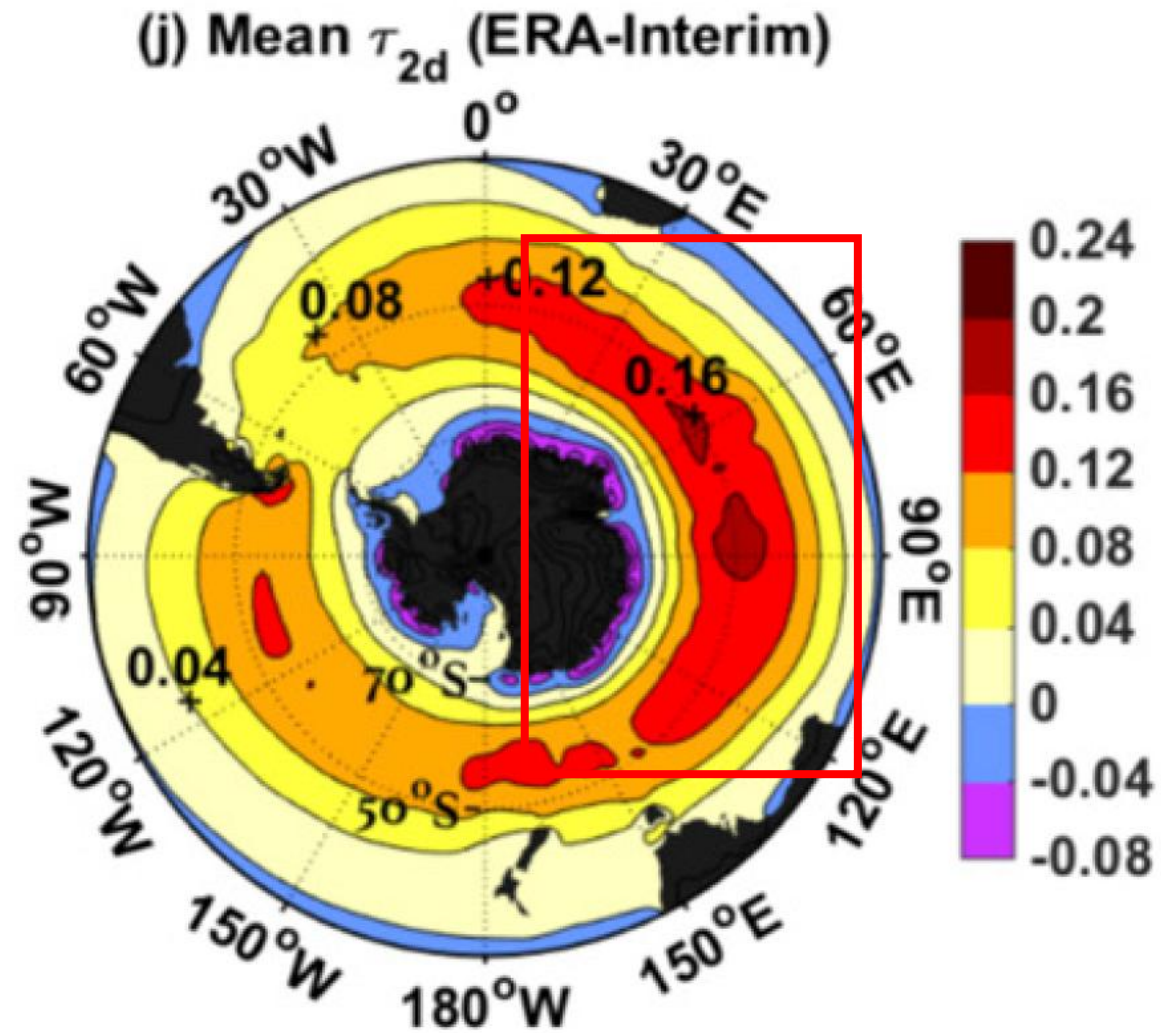
- 20% of its surface
- 25% of its primary production
- 40% of the carbon sink
- 70% of heat excess storage

f) Cumulative ocean heat uptake (10^9J/m^2)



Frölicher et al., 2015

2) Increased wind stress (N.m^2) : + 40 % (1979 -2016) (Lin et al. 2018, J. Climate)

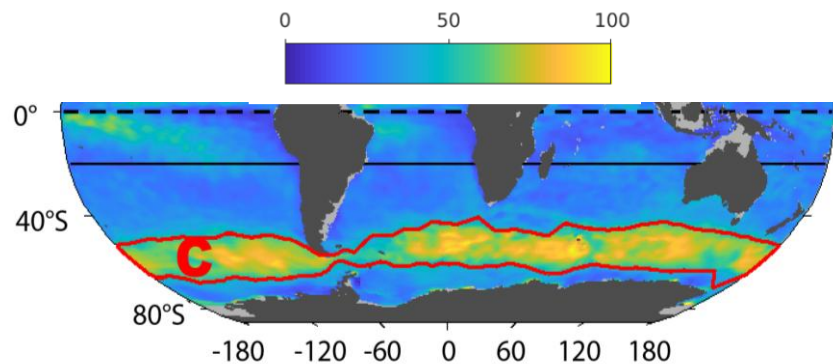


→ Meso-scale (eddies) activities
→ Mixed Layer depth

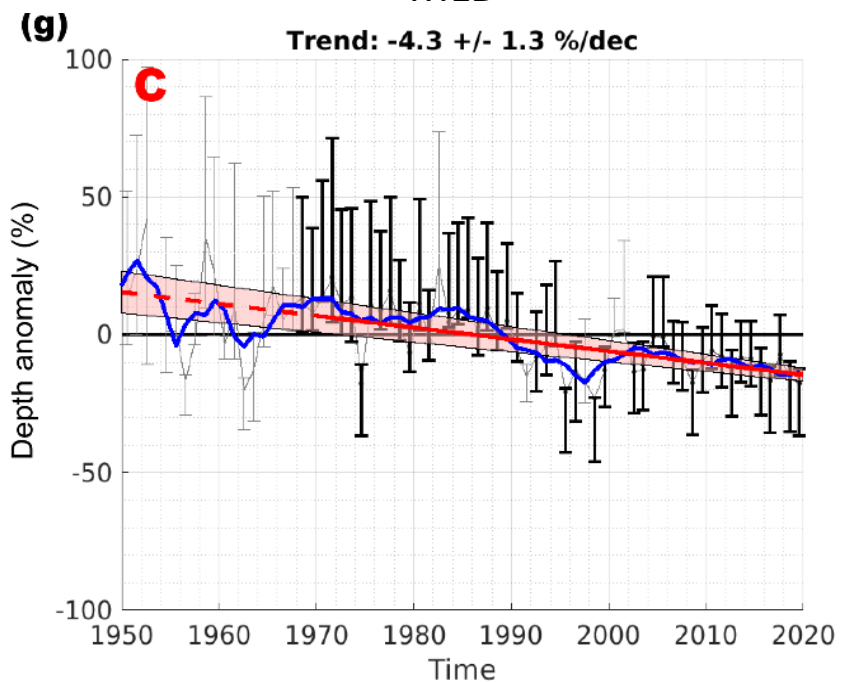
} → Phytoplankton nutrients

Increased Mixed Layer Depth (MLD)

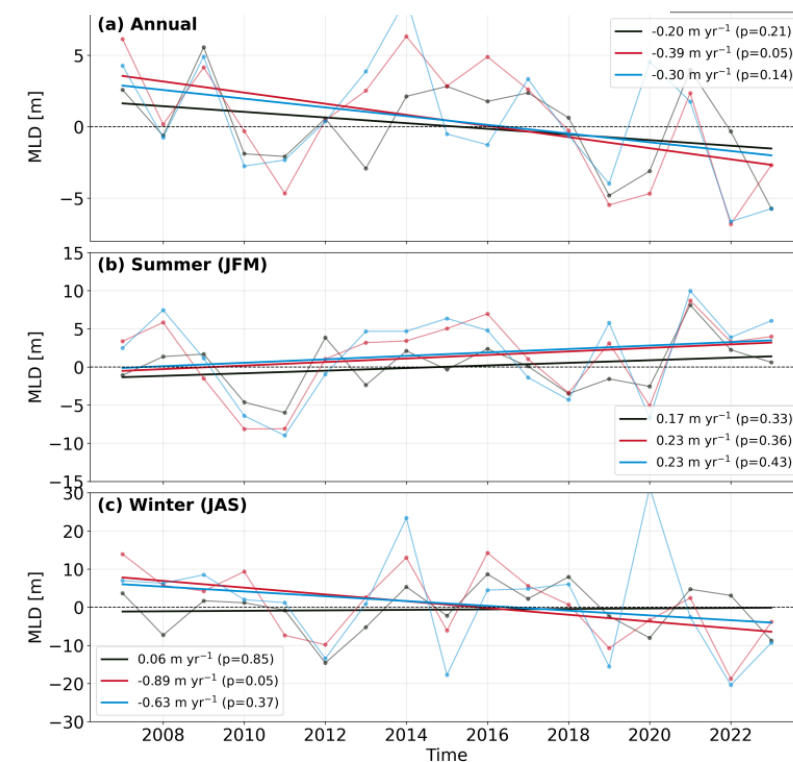
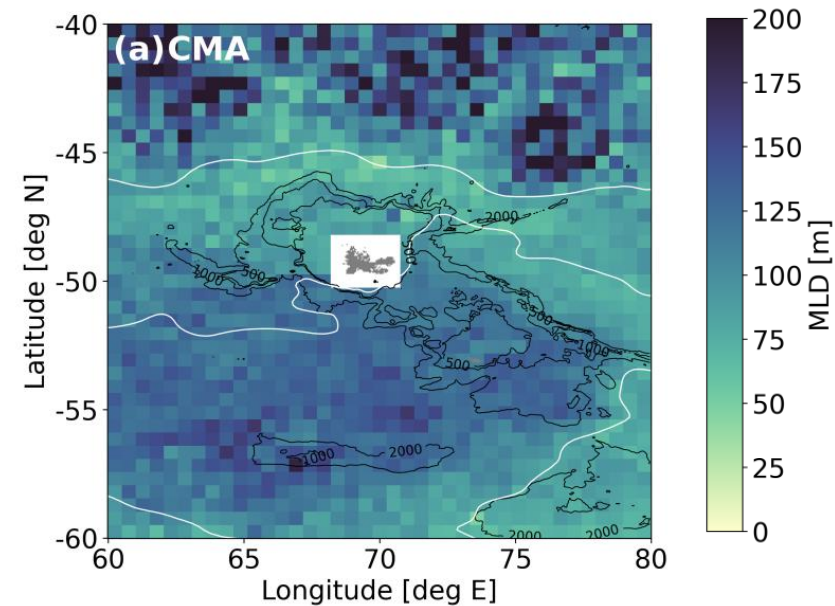
Summer MLD climatology



MLD

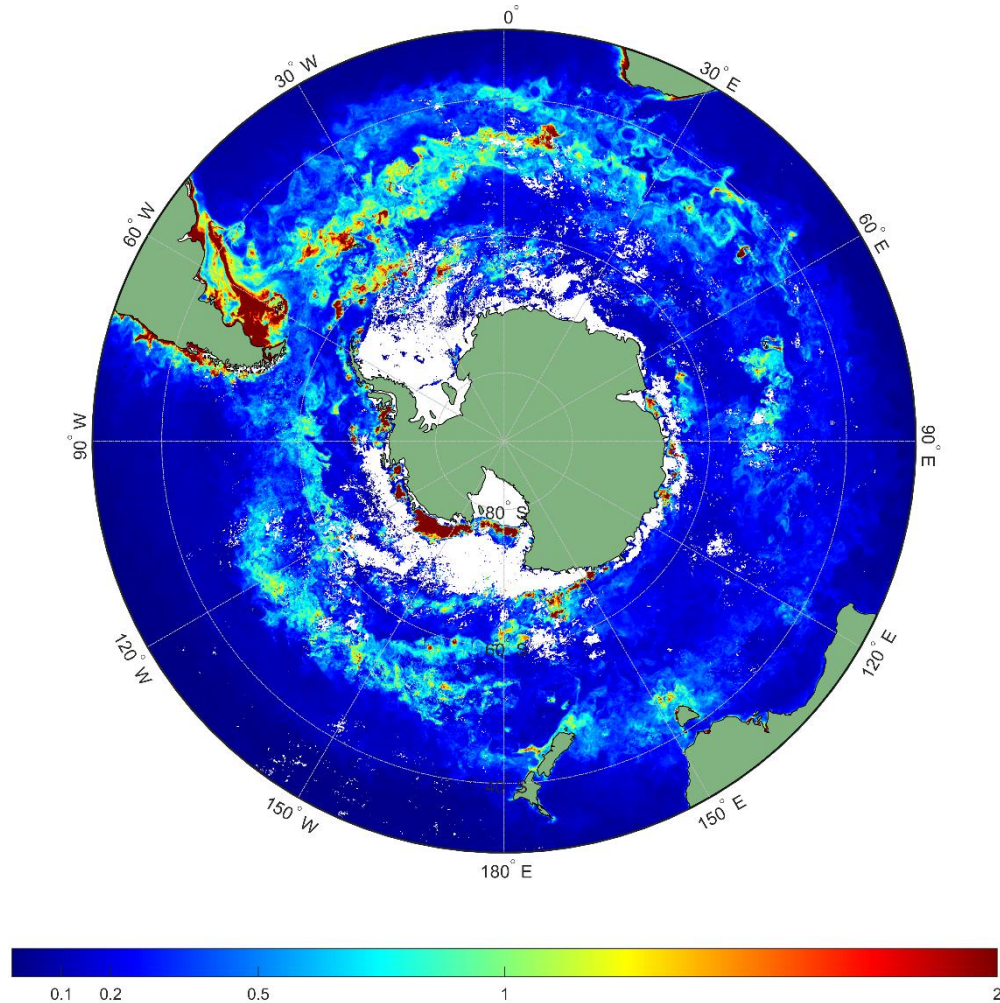


Sallé et al. Nature 2020



Doriot et al. in revision

Changes in the SO primary production

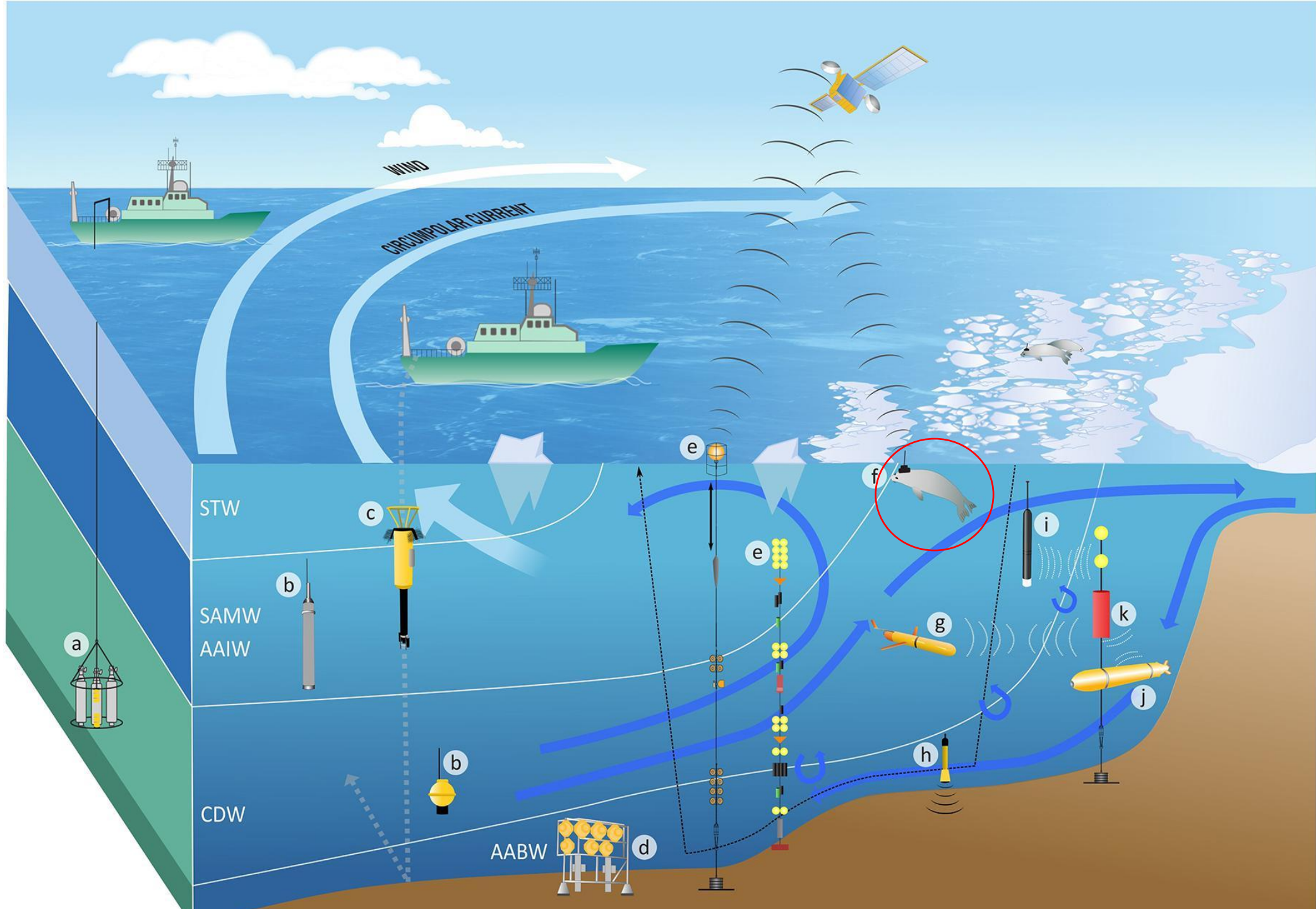


An increase of phytoplankton biomass¹

But a likely change in the composition of phytoplankton communities²

¹Del Castillo et al. 2019, GRL

²Mestre et al. 2020. PRSL













Mirounga leonina:
A seal of exception



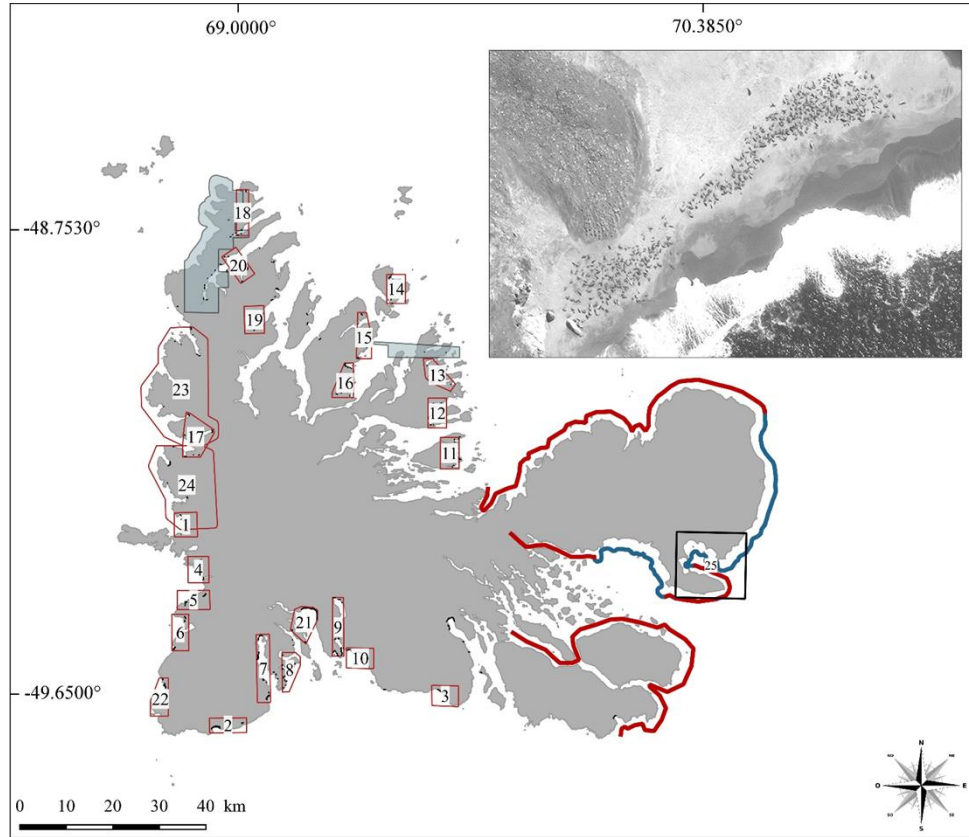




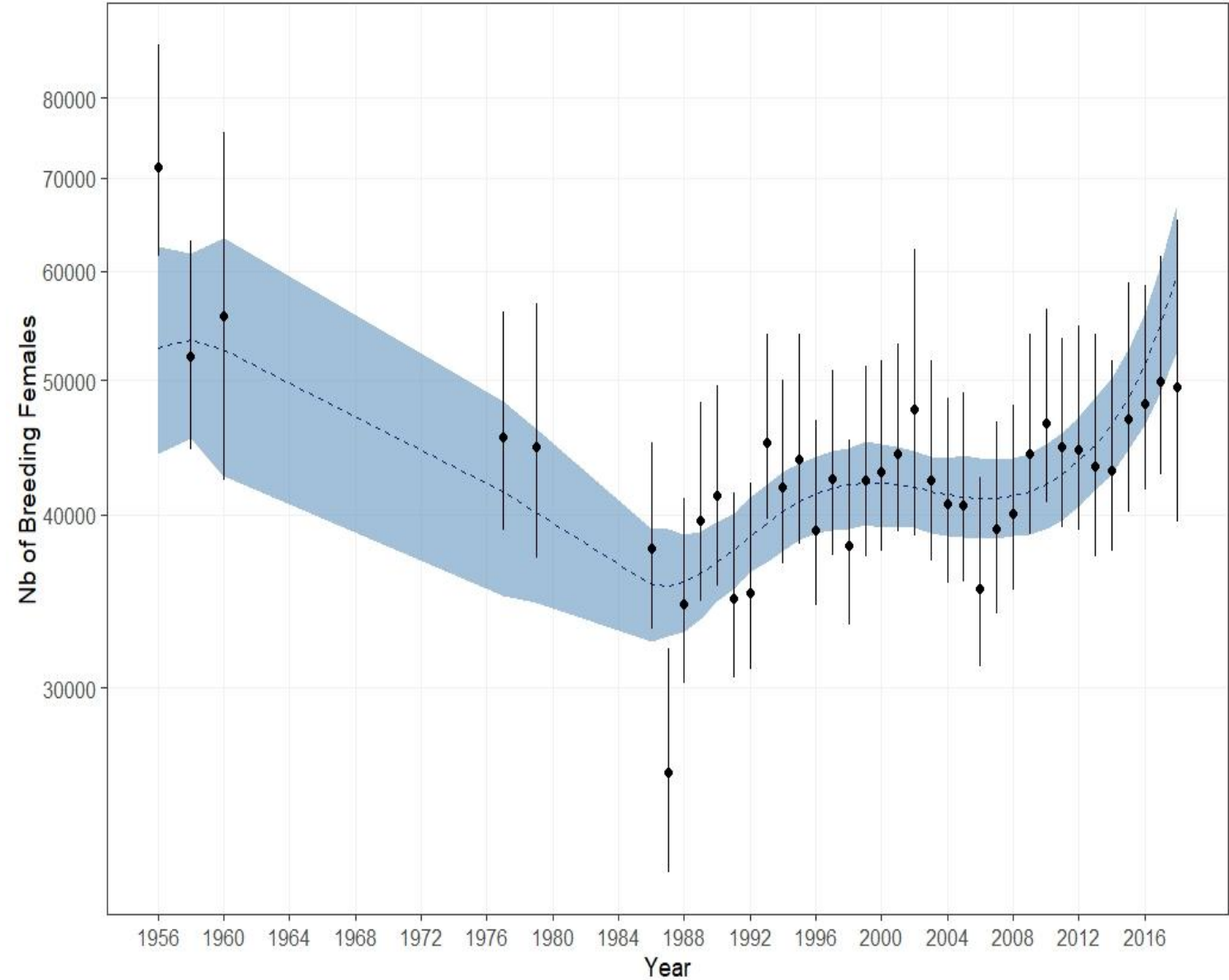


b

100 000 breeding females



LABORIE J, AUTHIER M, CHAIGNE A, DELORD K, WEIMERSKIRCH H, GUINET C (2023), Estimation of total population size of southern elephant seals (*Mirounga leonina*) on Kerguelen and Crozet archipelagos using very high-resolution satellite imagery. *Frontiers in Marine Science*. 10:1149100, DOI: 10.3389/fmars.2023.1149100





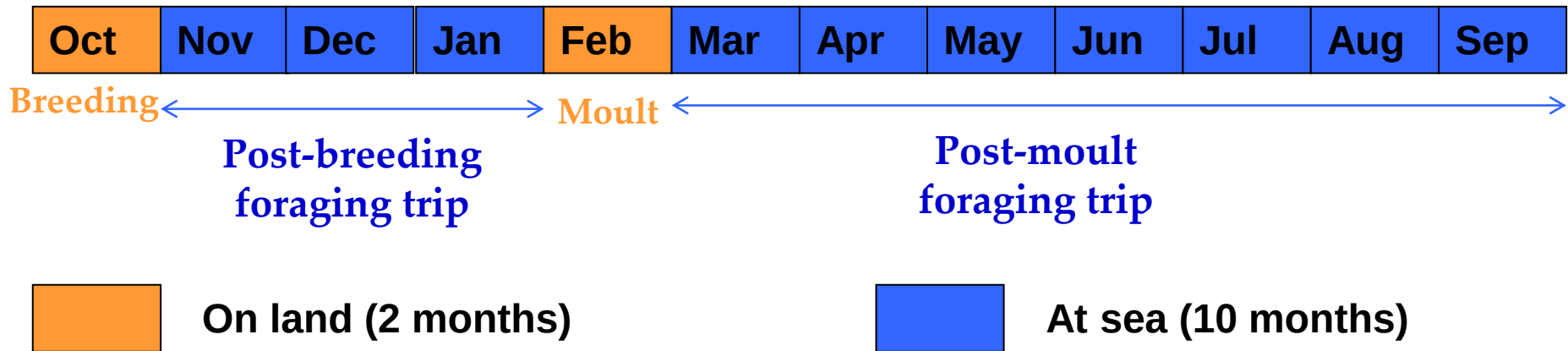


Elephant seals are the largest seals

- males 2-3 tons; 4,3 m, 10-11 year, 14 years

- females 300-600 kg; 2,3 m, 3-4 year, 18 years



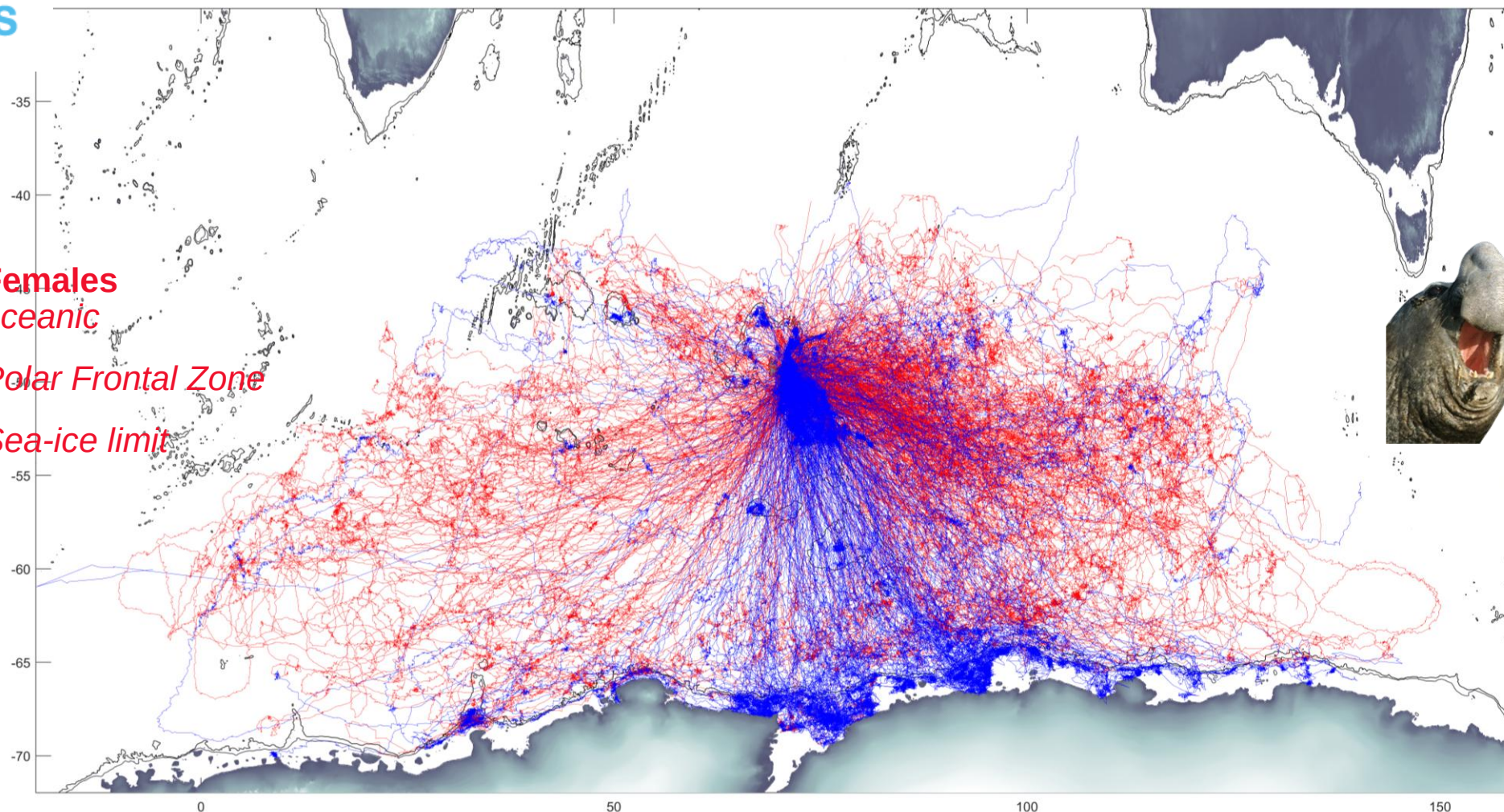




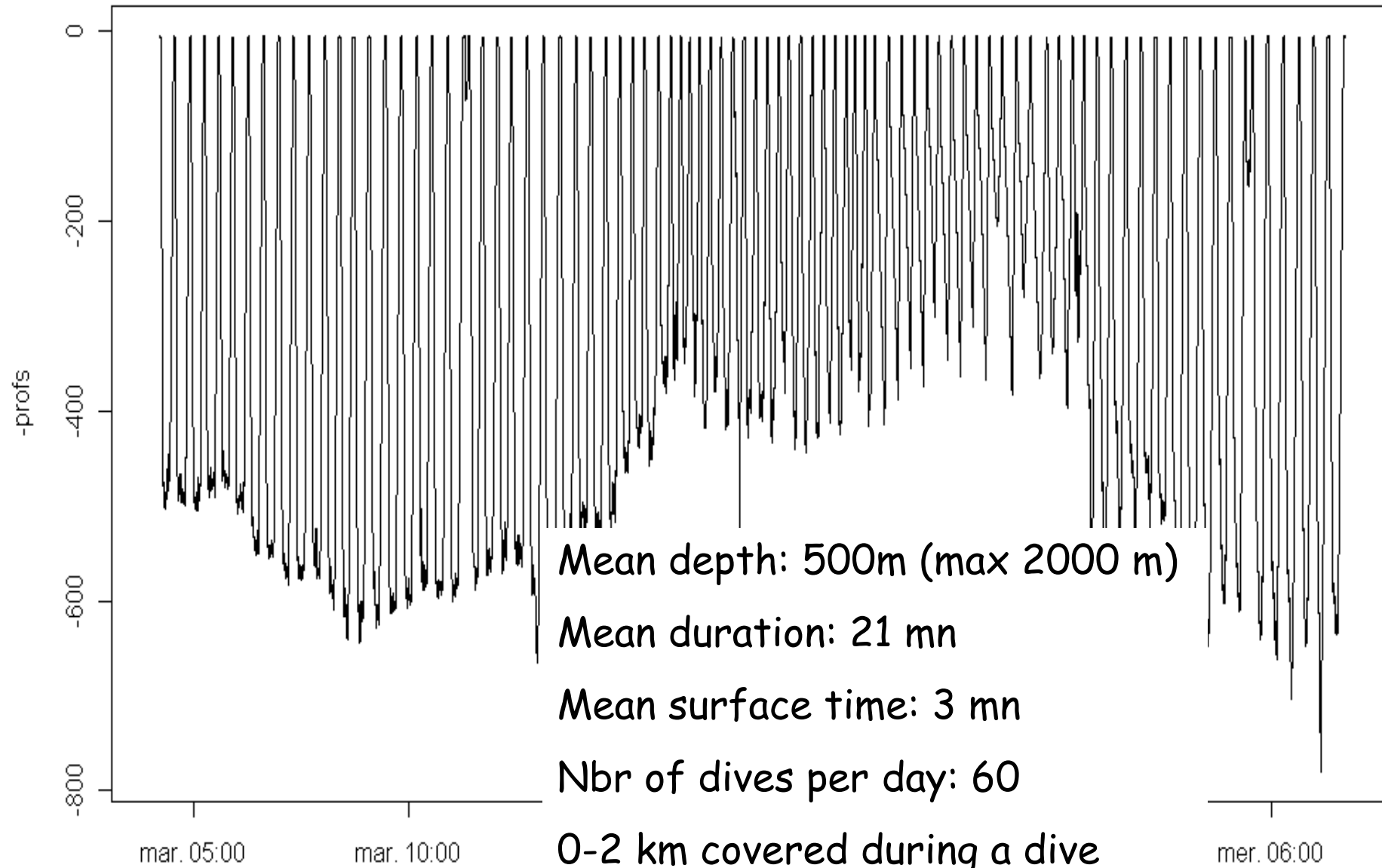


Males
Benthic
Kerguelen &
Antarctic shelf

Females
oceanic
Polar Frontal Zone
Sea-ice limit



Post Molt (7 month) : Mean = 8 578 km (max 14 562 km)



Ice-edge feeding April-May

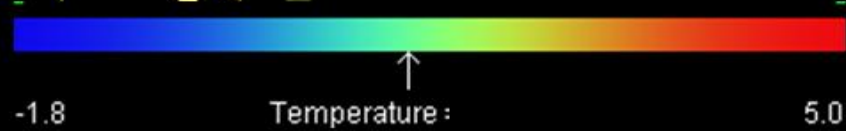


Outward : June 2004

Inward : March 2004 (2000 km)

Kerguelen

Temperature Section Kerguelen to Antarctica
March-June 2004 Seal 9934 (Guillaume)



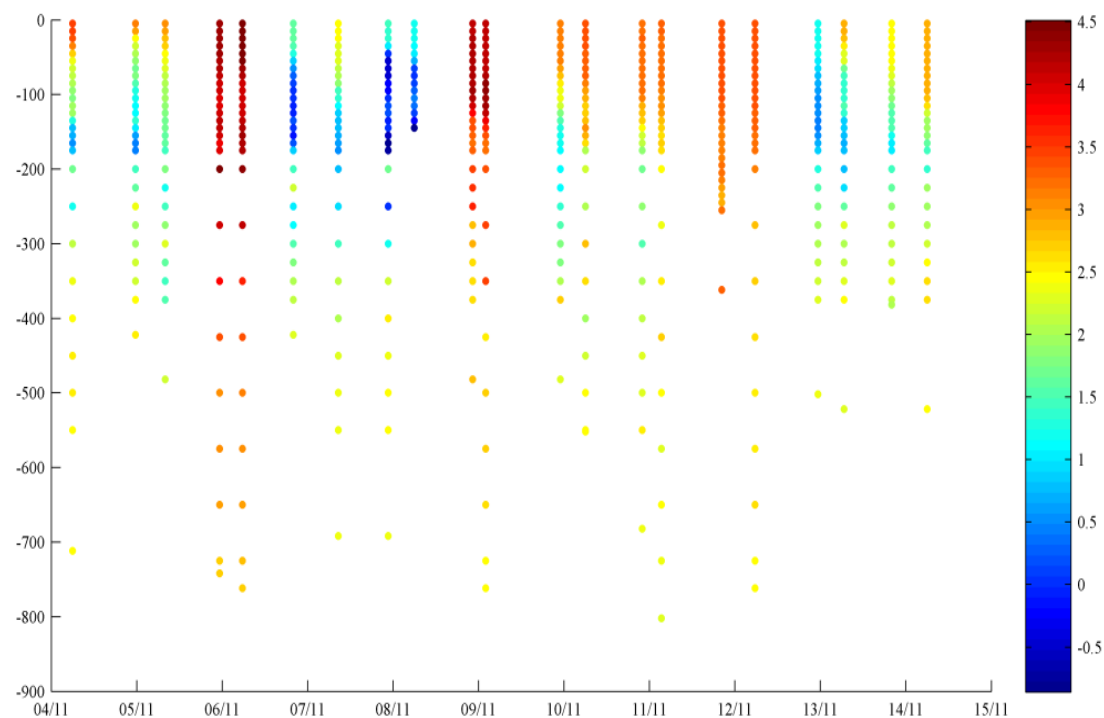
MERCATOR
OCEAN
INTERNATIONAL



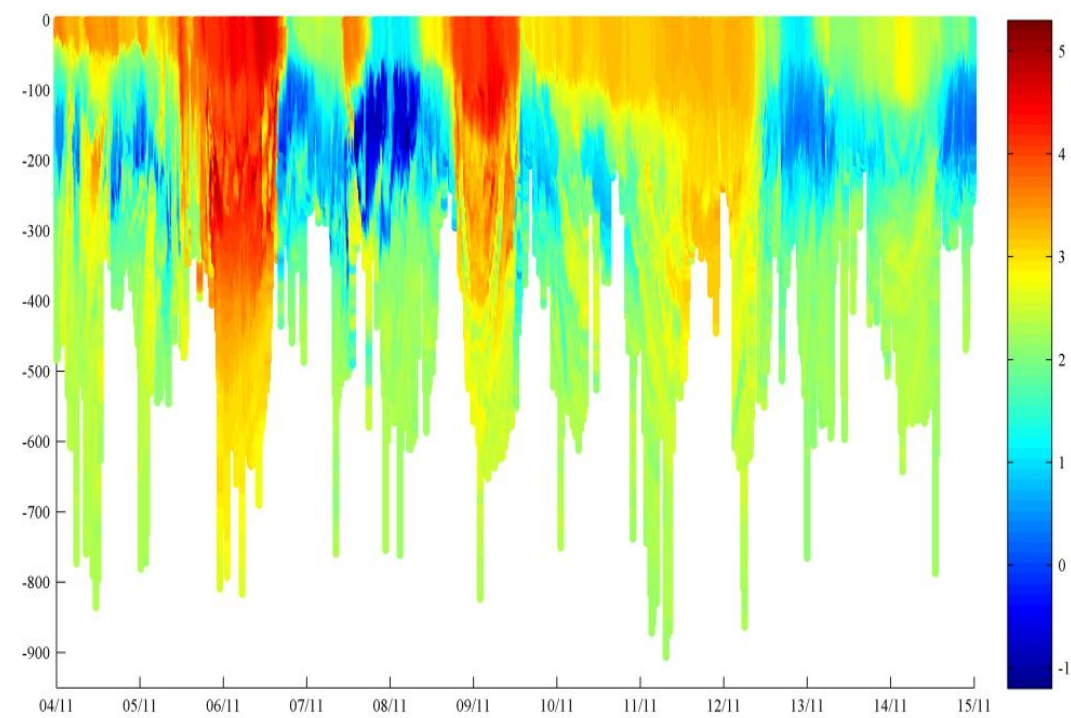
cnes

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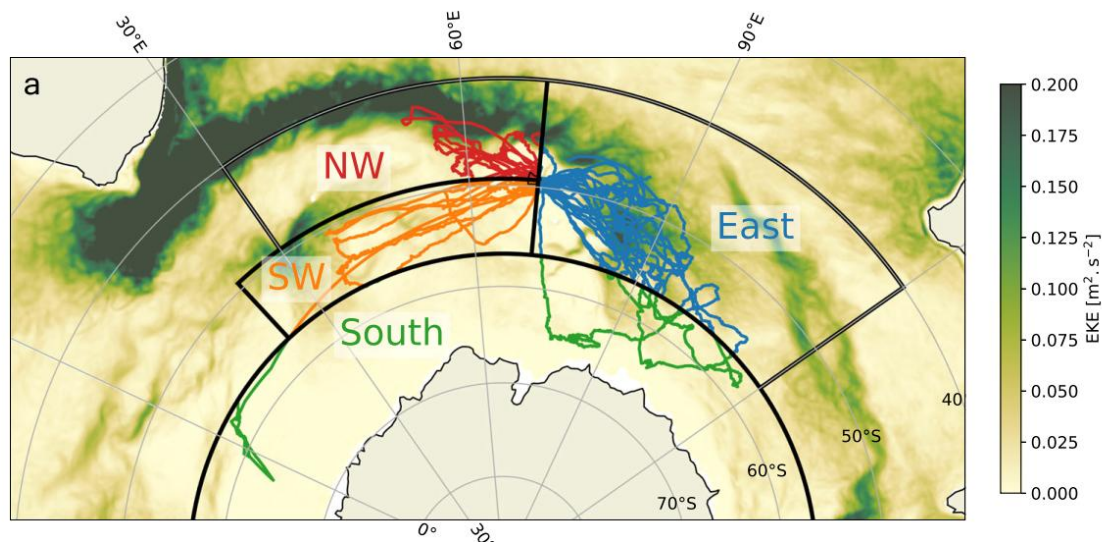


Temps réel basse résolution (27 pt) précision 0.03°C

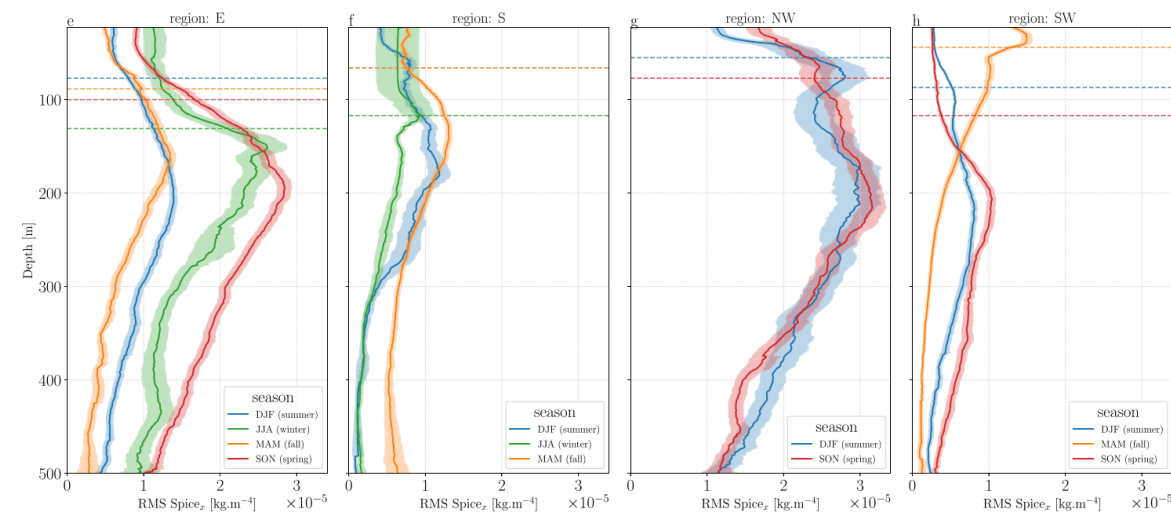


Temps différé haute résolution (1Hz) précision 0.1°C

Deep submesoscales in the Southern Ocean, revealed by elephant seals



Tracks, at sub-kilometre resolution, of 25 elephant seals fitted with HR CTD tags (0.5 Hz), 2014-2020.



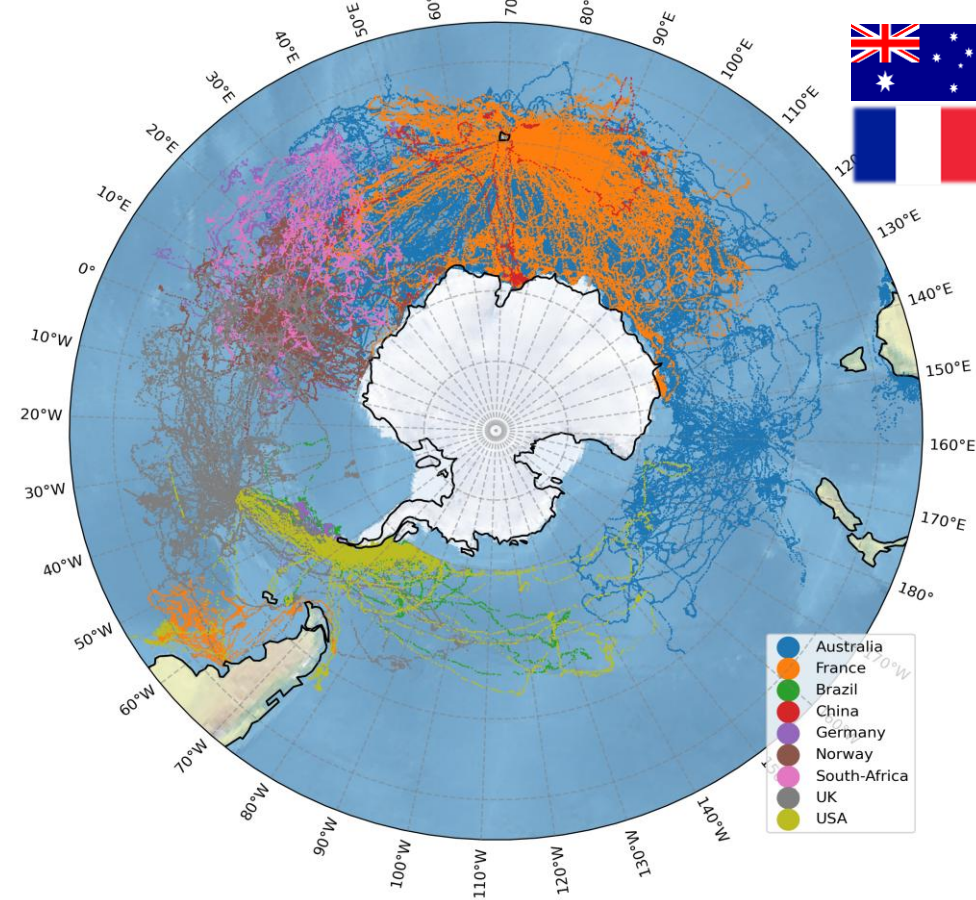
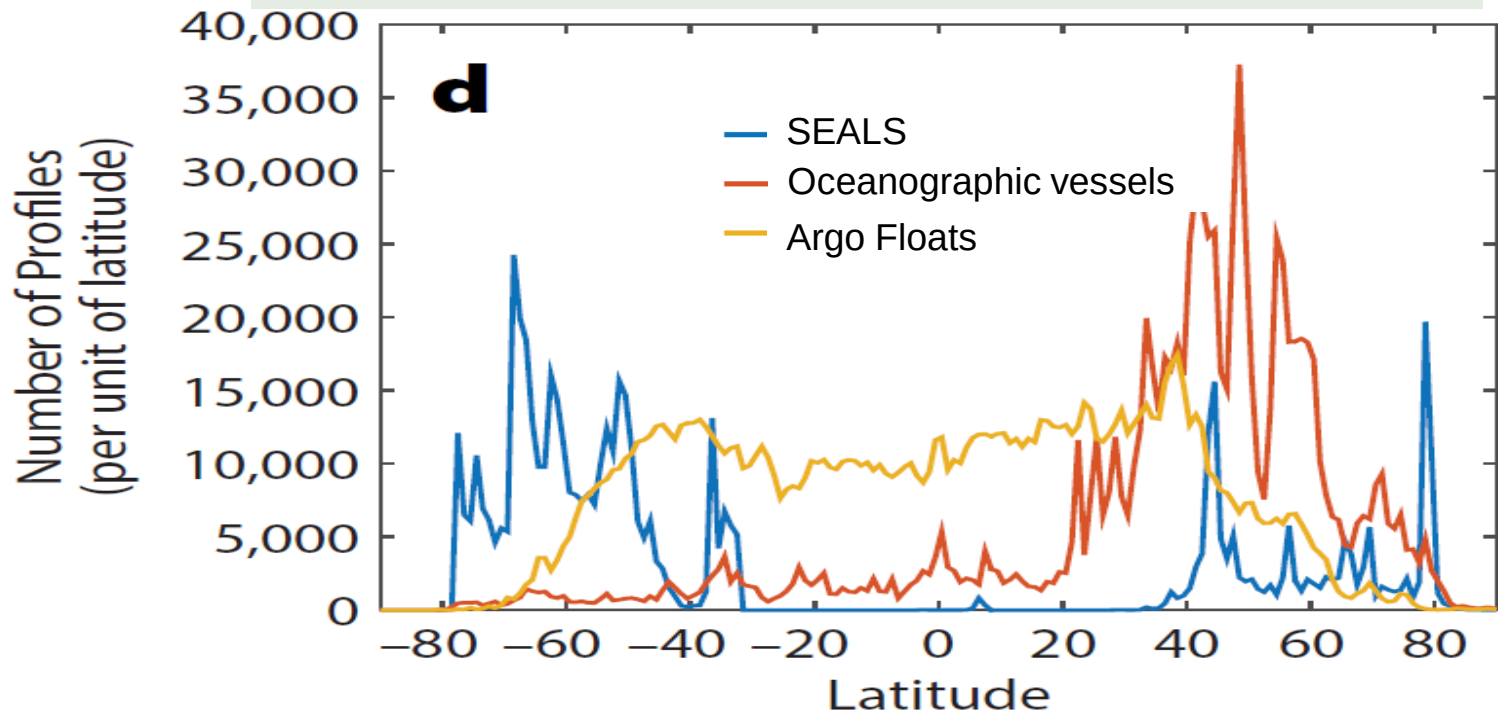
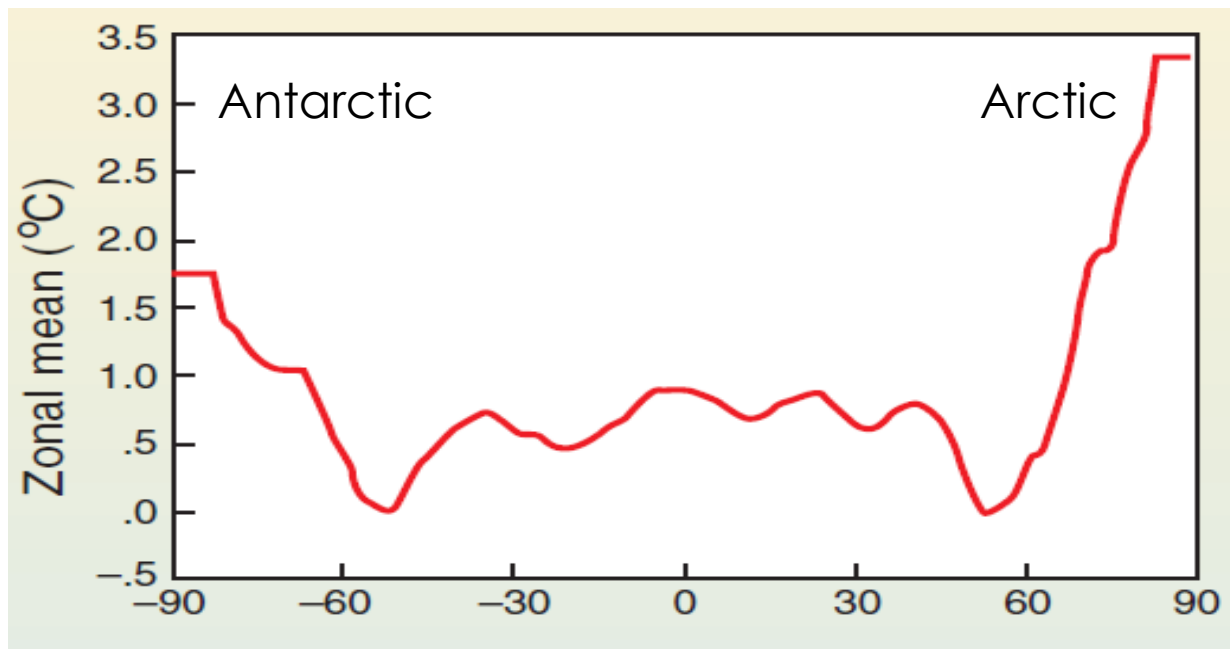
Seasonality: lateral buoyancy gradient (x-axis) vs depth. Left to right: East, South, North-west, South-east. **Blue** summer, **green** winter, **orange** autumn, **red** spring. Dashed lines: mean mixed-layer depth.

Key findings

- 133,598 dives
- Fronts intensified beneath the mixed layer
- Year-round, from the surface to at least 500 m
- Seasonal cycle: peak in austral spring, low in autumn
- Correlates with surface eddy kinetic energy ($r = 0.86$)

Scientific significance and outlook

- Likely driver: frontogenesis induced by mesoscale eddies
- Strong vertical velocities expected, up to 100 m per day
- Heat and nutrient transports underestimated at depth
- Outlook: pair instrumented seals with SWOT altimetry



80 % of the T/S profiles South of 60°S
98 % of the T/S profiles within the
Antarctic sea ice



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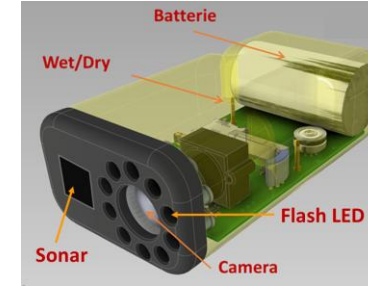
CTD-Fluo + light



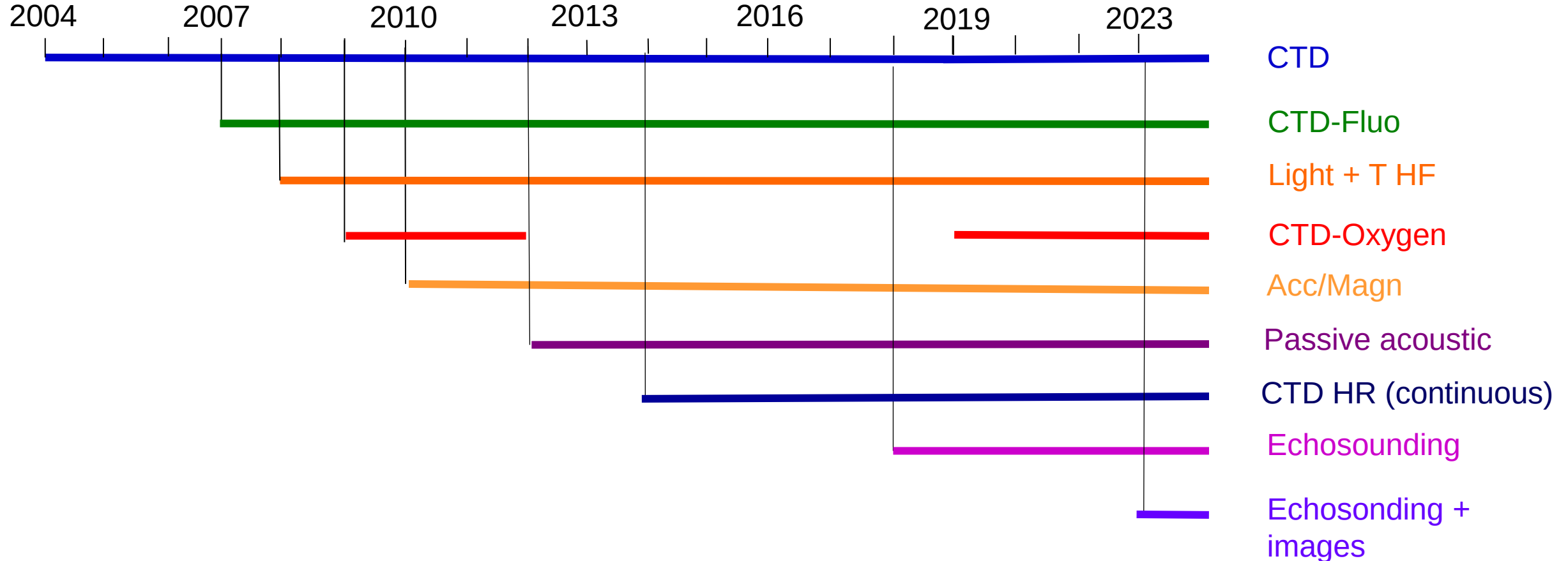
CTD-Oxygen



CTD- passive
acoustic



Echosounding +
images



The power of biologging to address ecological and environmental questions:

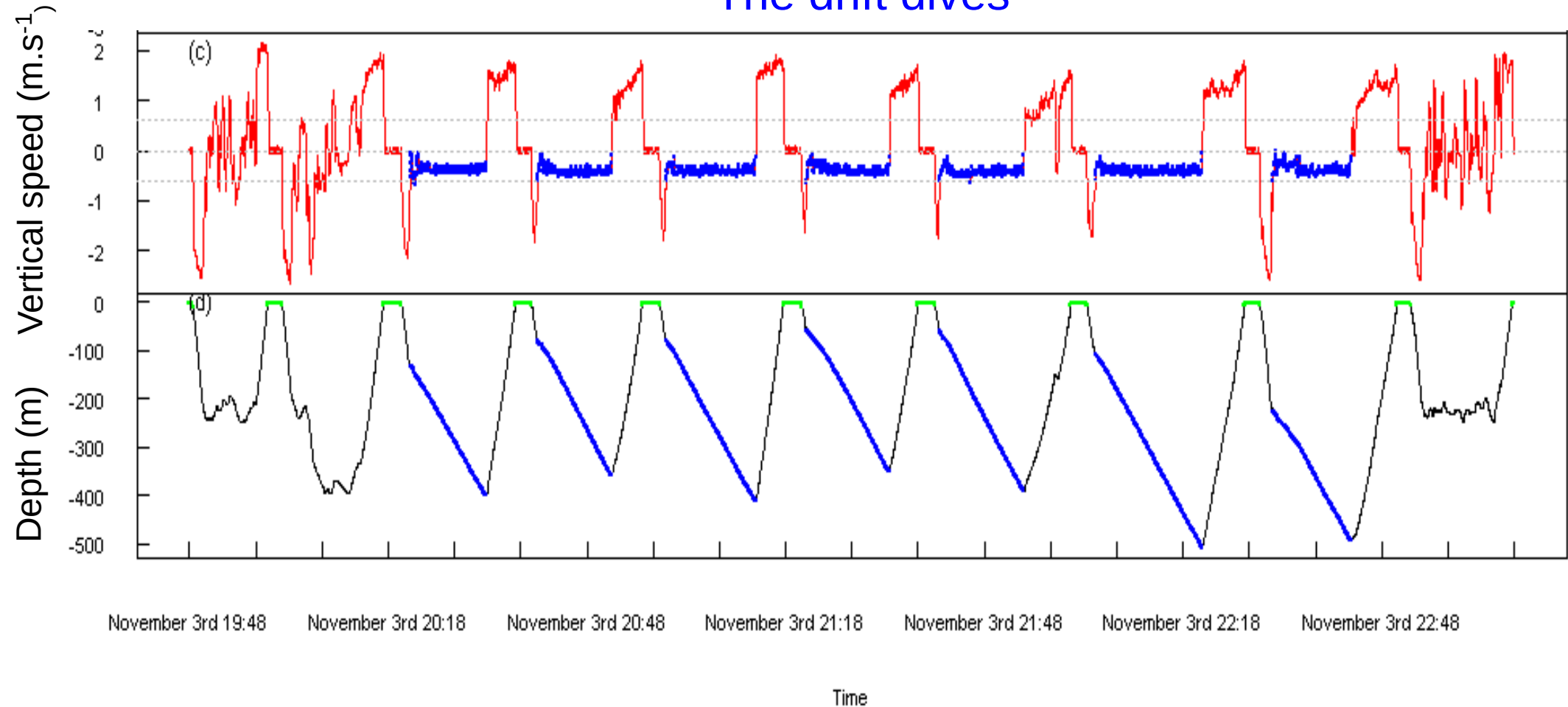


Hydrophone

Accelerometer,
Magnetometer,

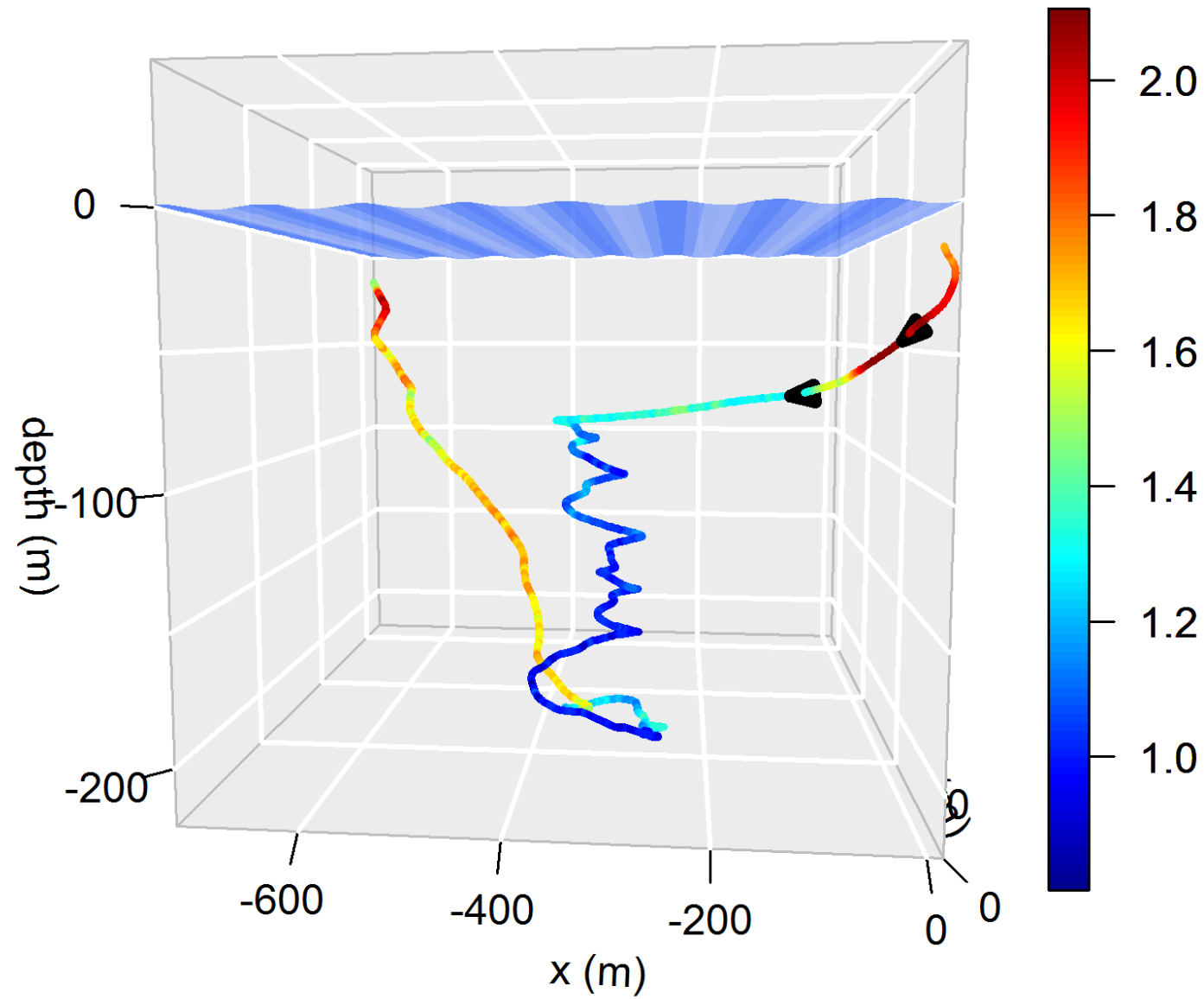
Pressure sensor,
GPS,
Light sensor,
Temperature sensor

Evaluating the bouyancy (condition) change of Southern Elephant Seals through their foraging trip The drift dives



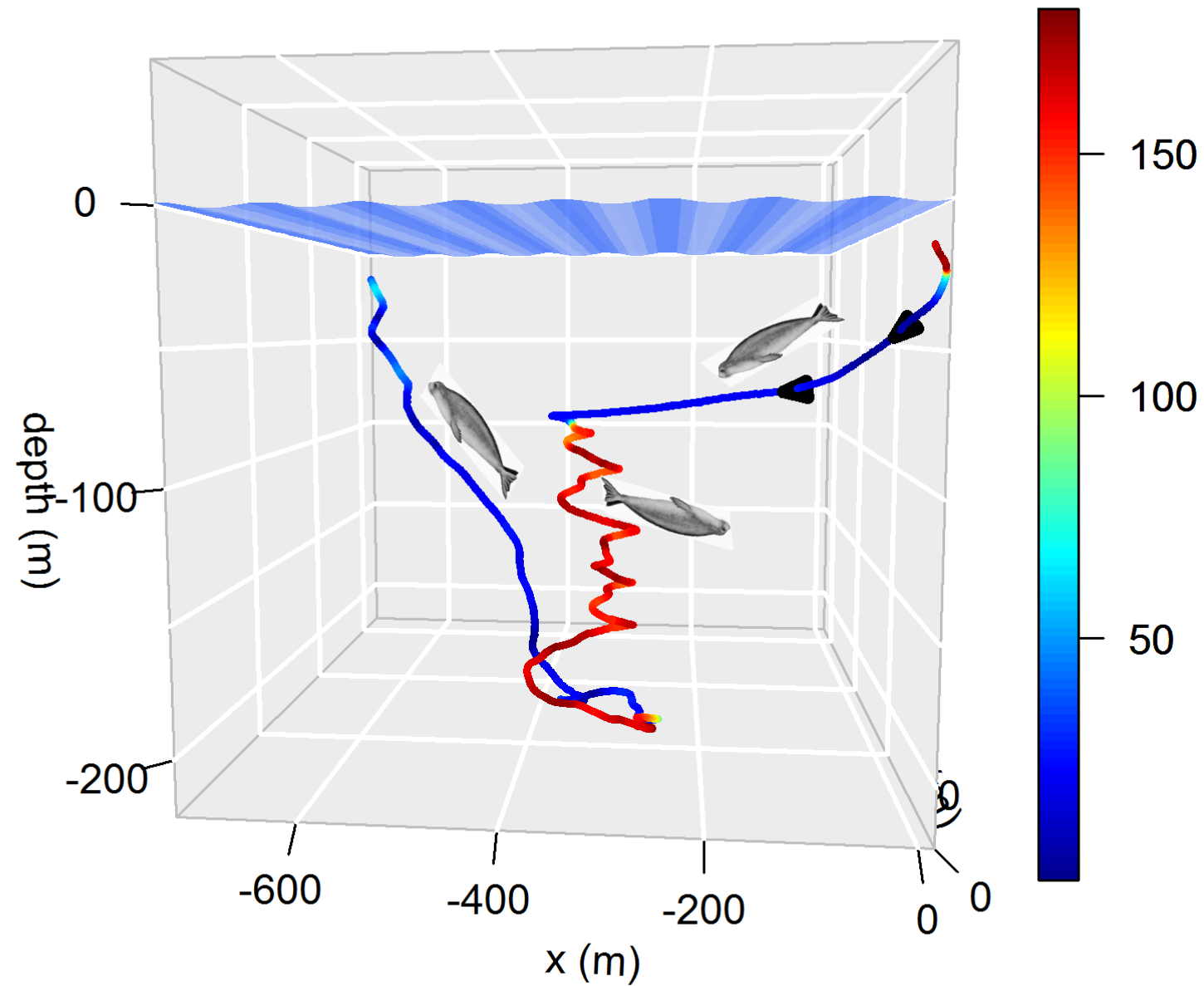
Dive 85

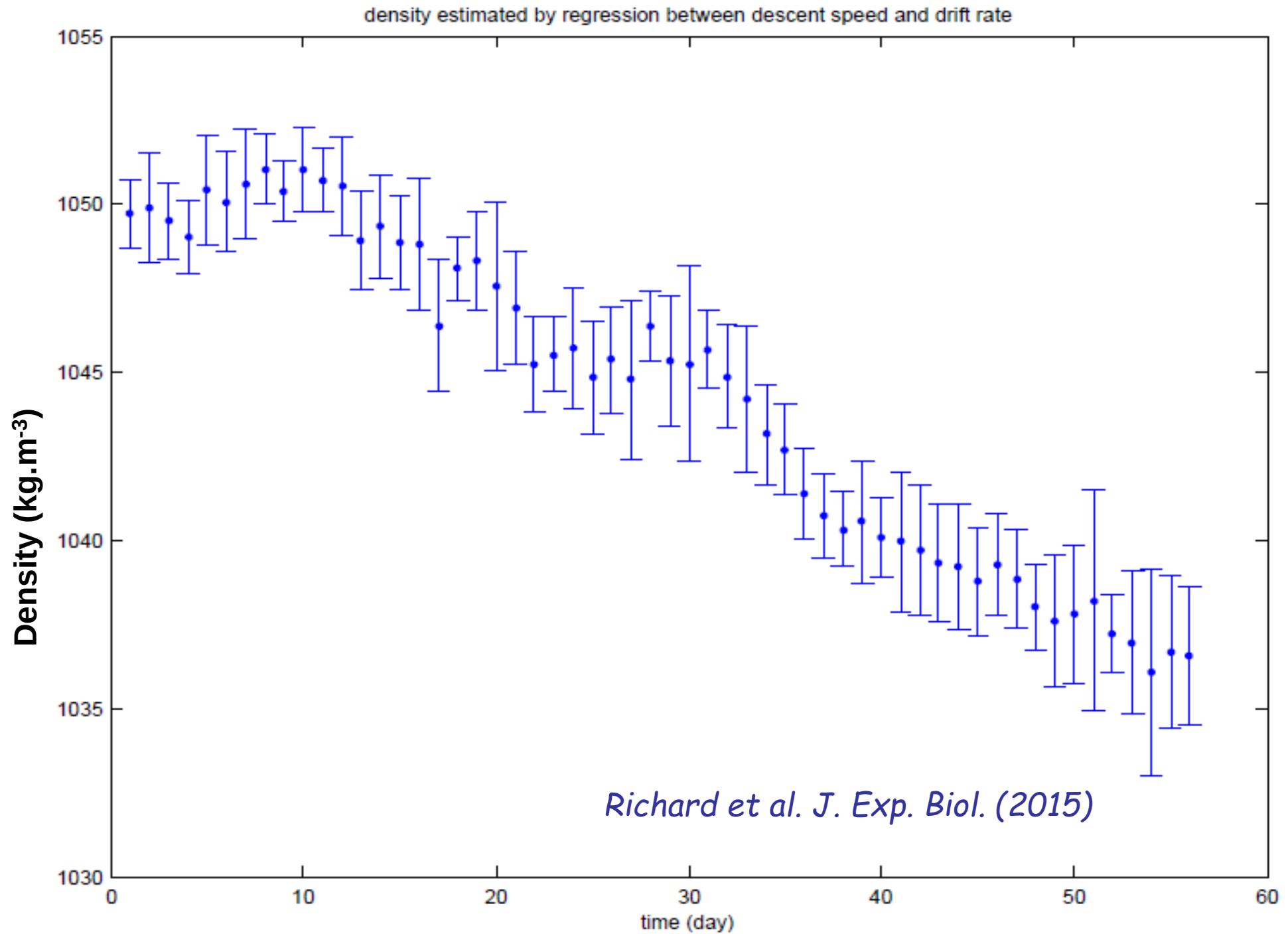
Speed (m/s²)



Dive 85

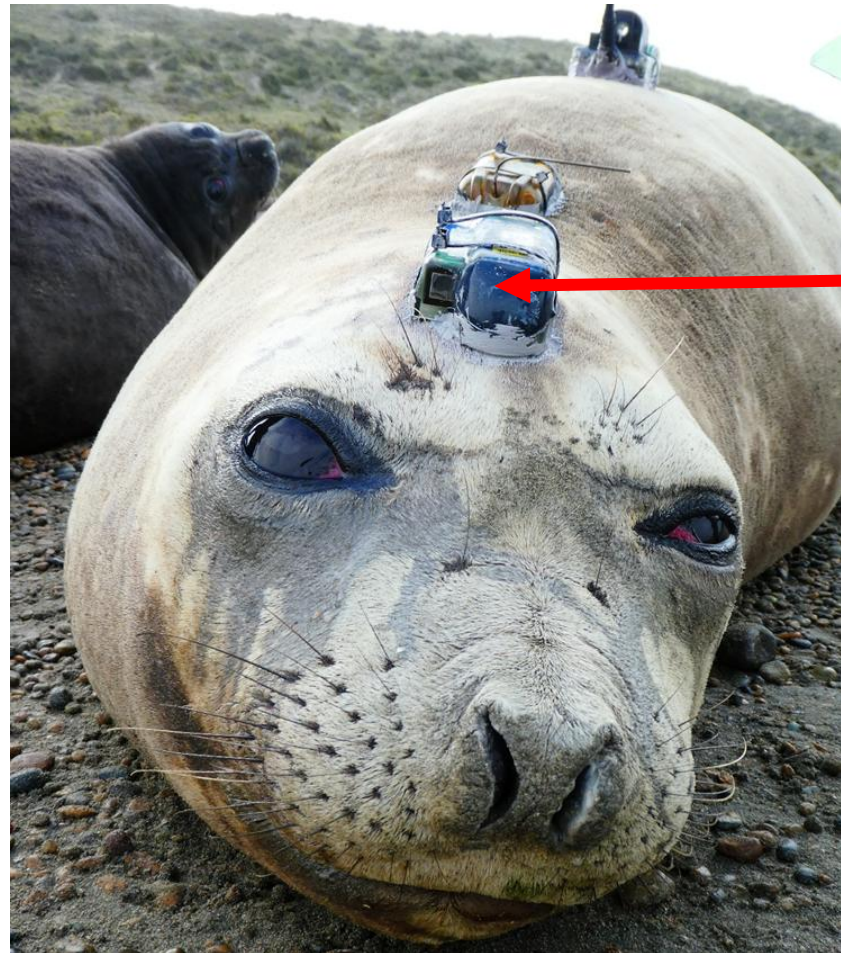
Roll (°)





The power of biologging to address ecological and environmental questions:

The case of passive acoustic as an example

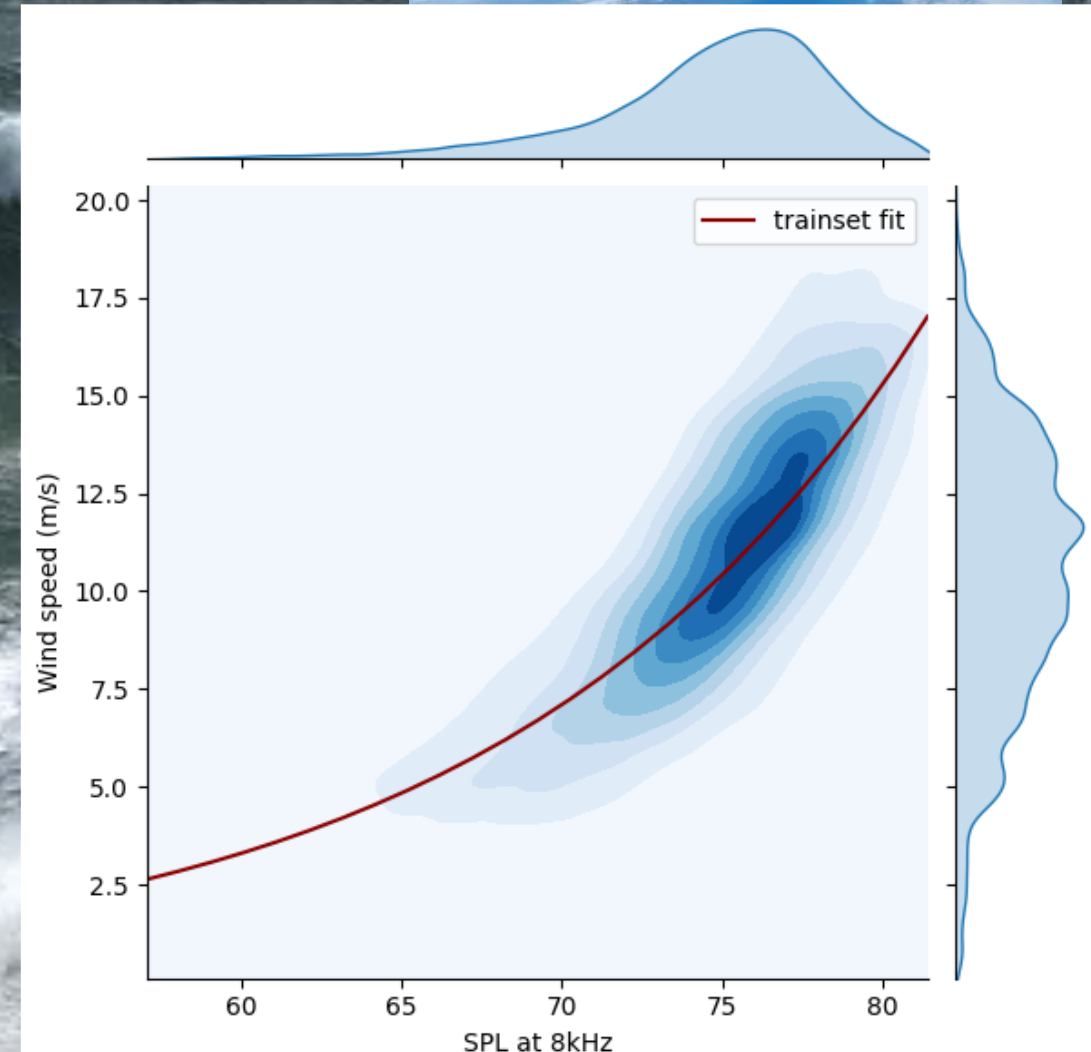
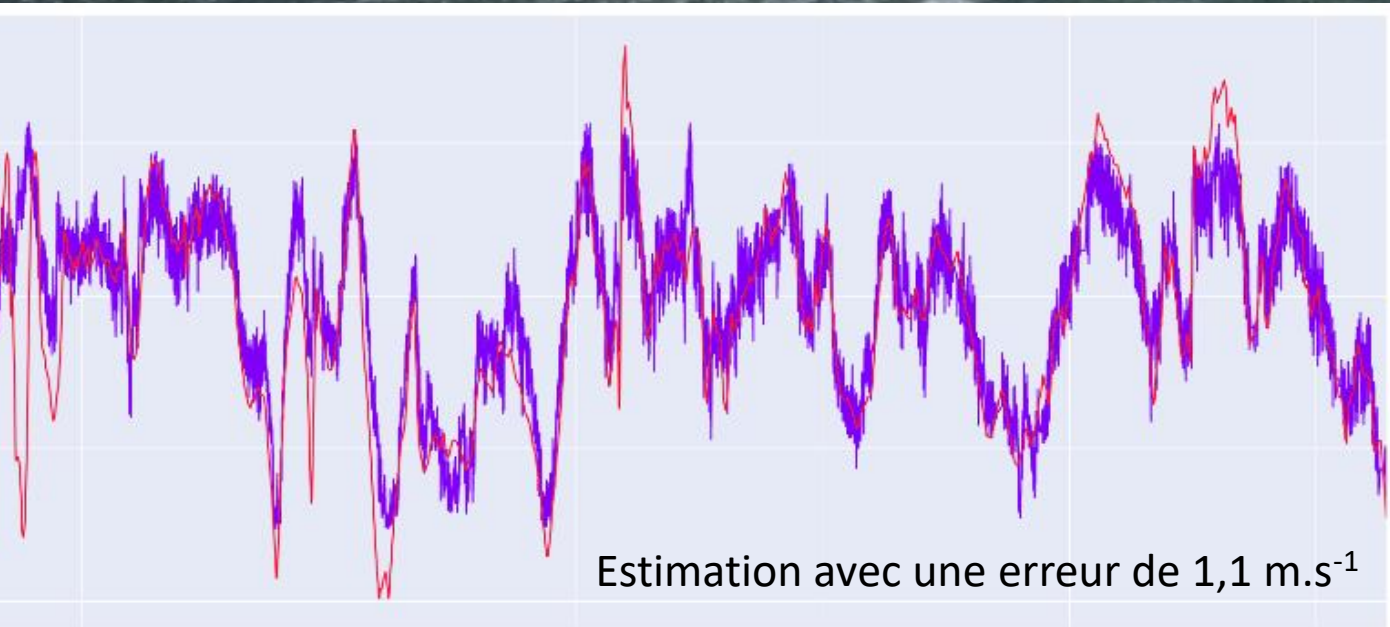


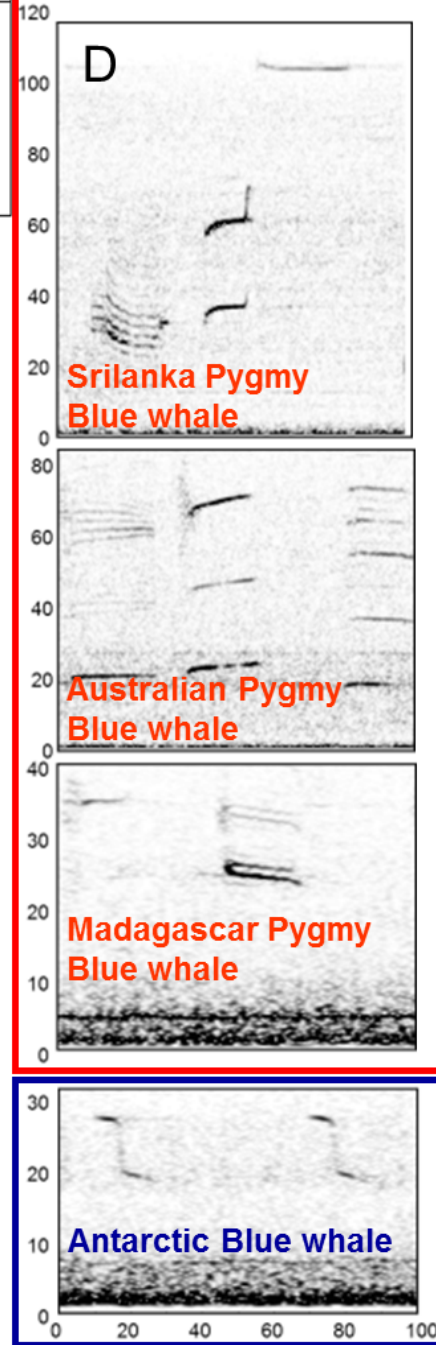
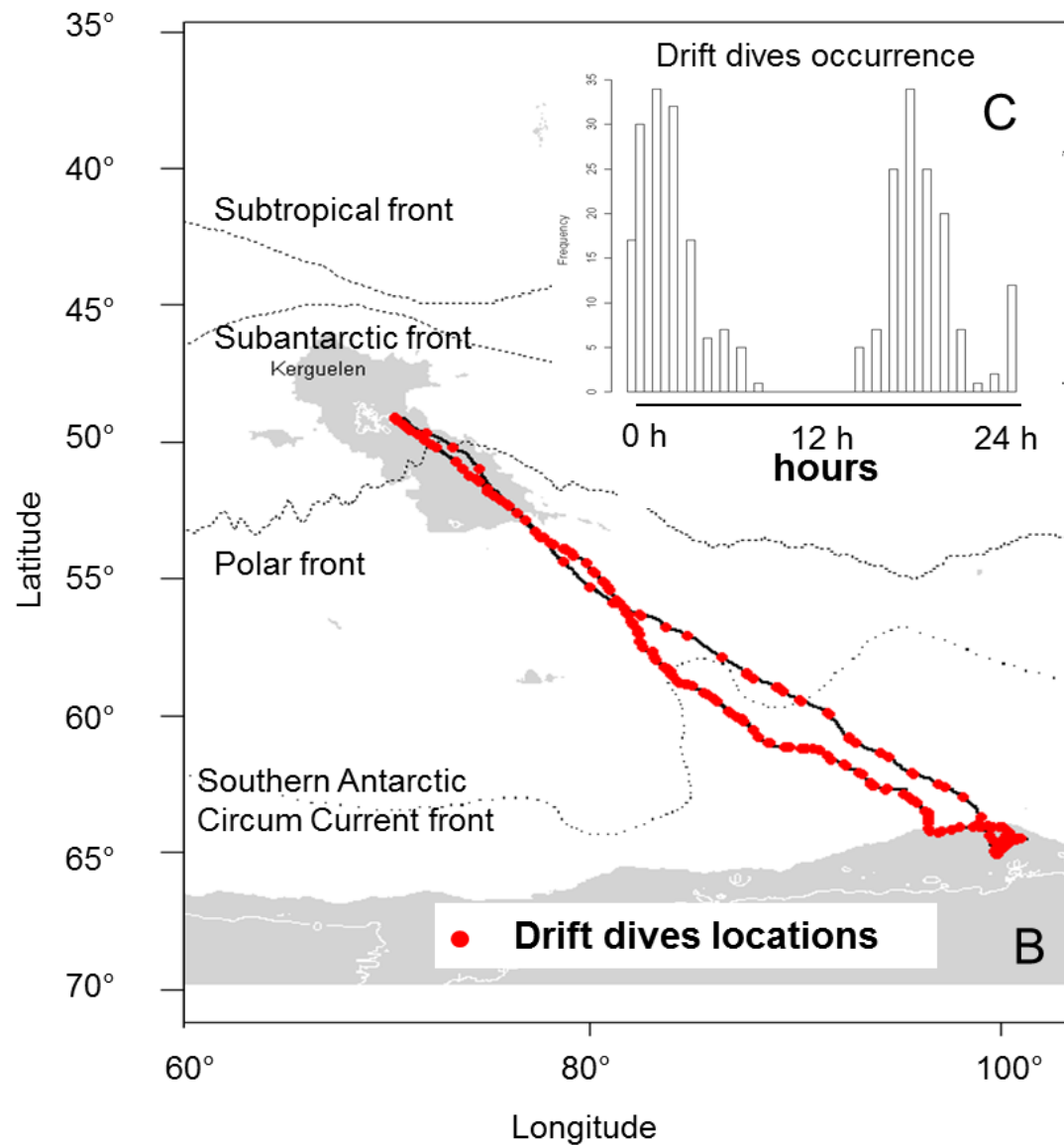
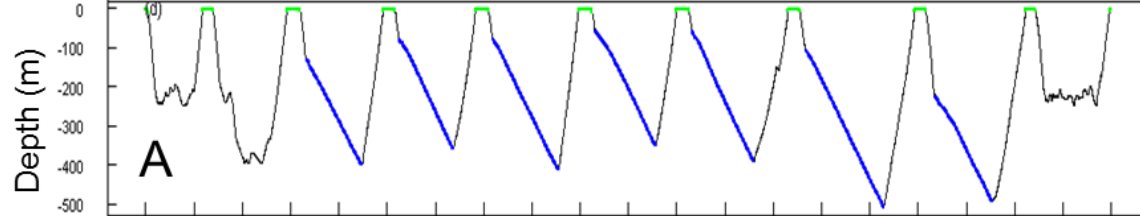
Hydrophone

Accelerometer,
Magnetometer,

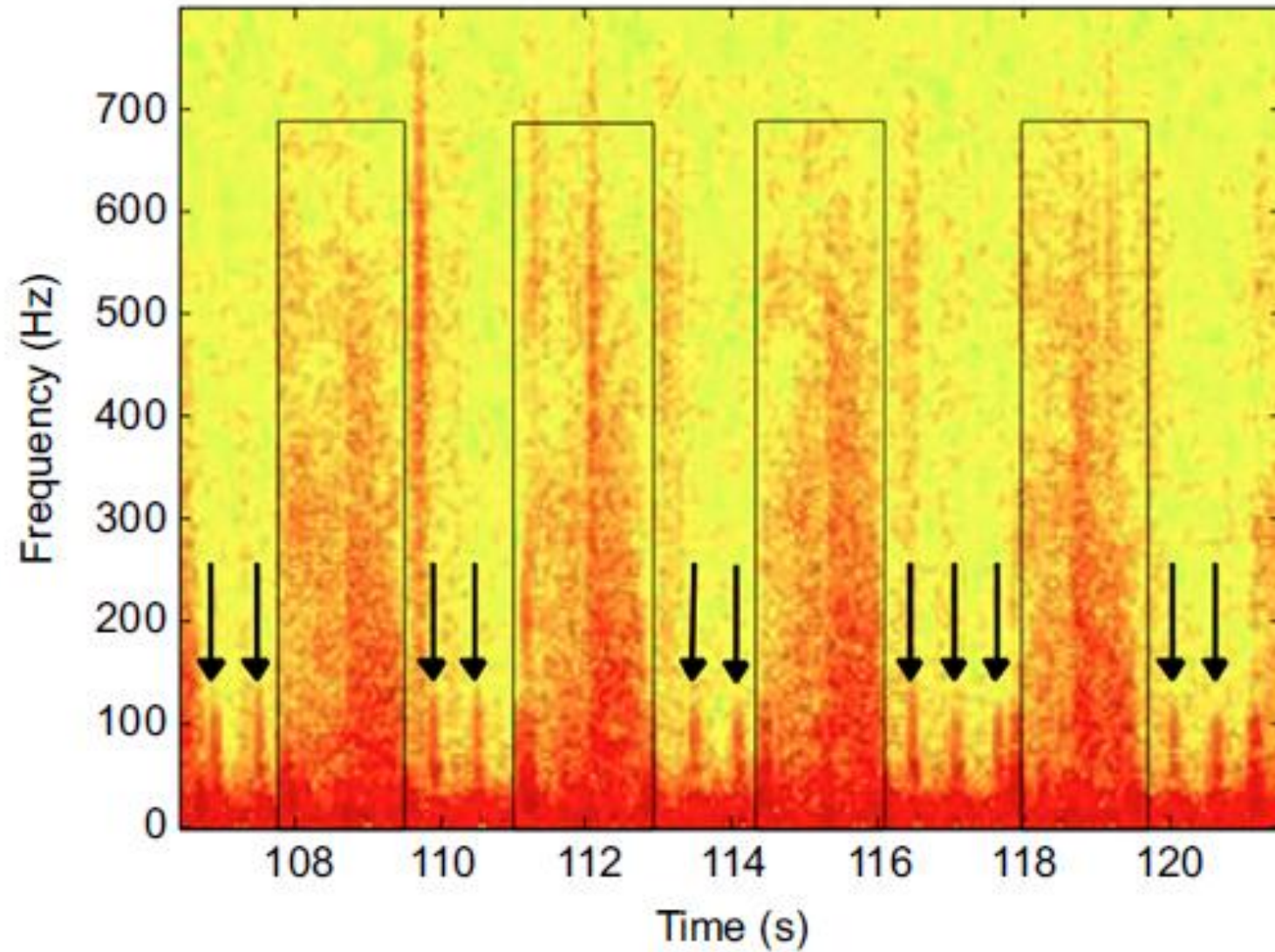
Pressure sensor,
GPS,
Light sensor,
Temperature sensor

Wind and sea-state





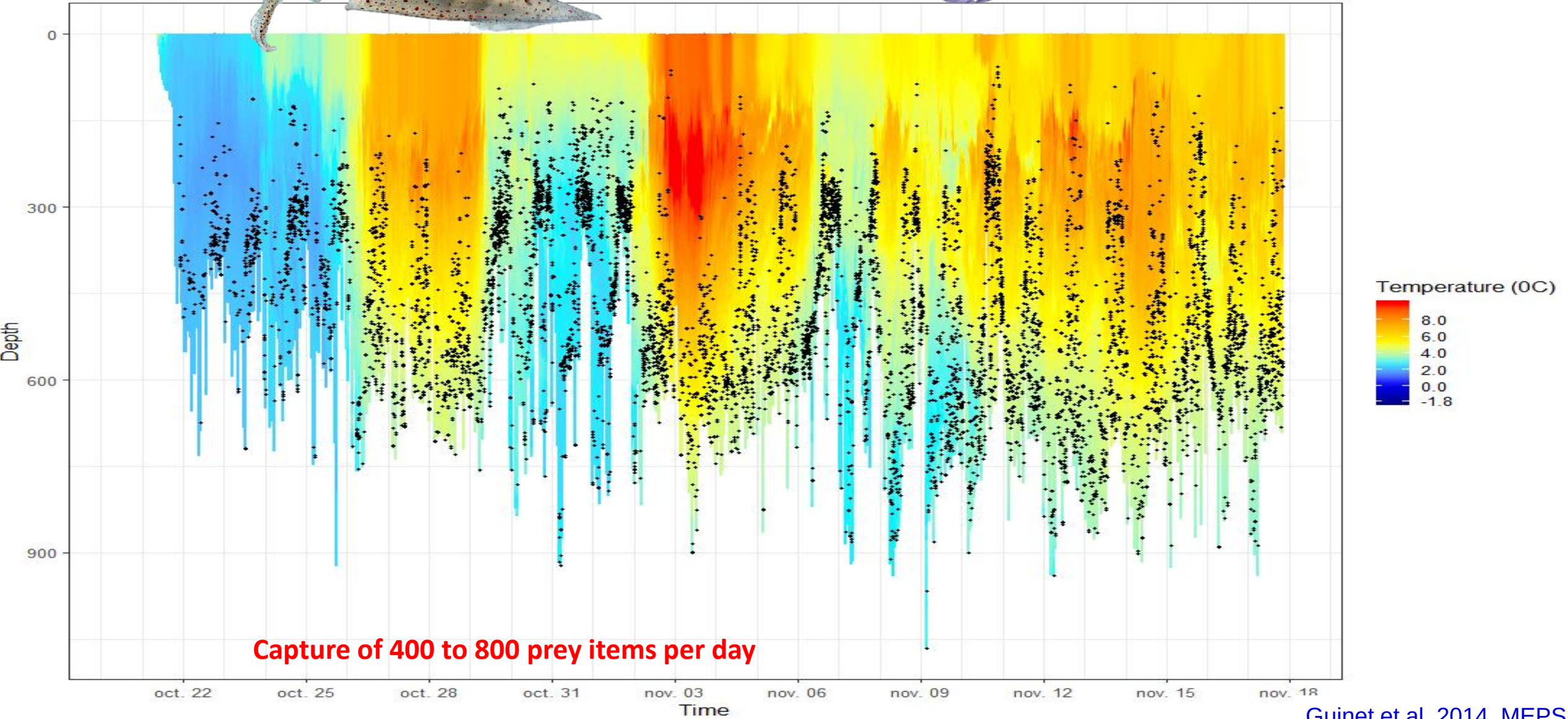
Gros-Martial et al. 2026. *Frontiers in Marine Science*



Genin A. Richard, G., Jouma'a J., Picard B., El Ksabi N., Vacquie Garcia J., Guinet, C. (2015). Marine Mammal Science.

Day L., Jouma'a J., Bonnel J., Guinet C. (2017) Journal of Experimental Biology.

1) Prey catch attempts



Every year 15 females southern Elephant seals are equipped with Oceanographic tags and biologgers :

Perform
153000
dives

Cover 6.2
millions
 km^2 of the
SO

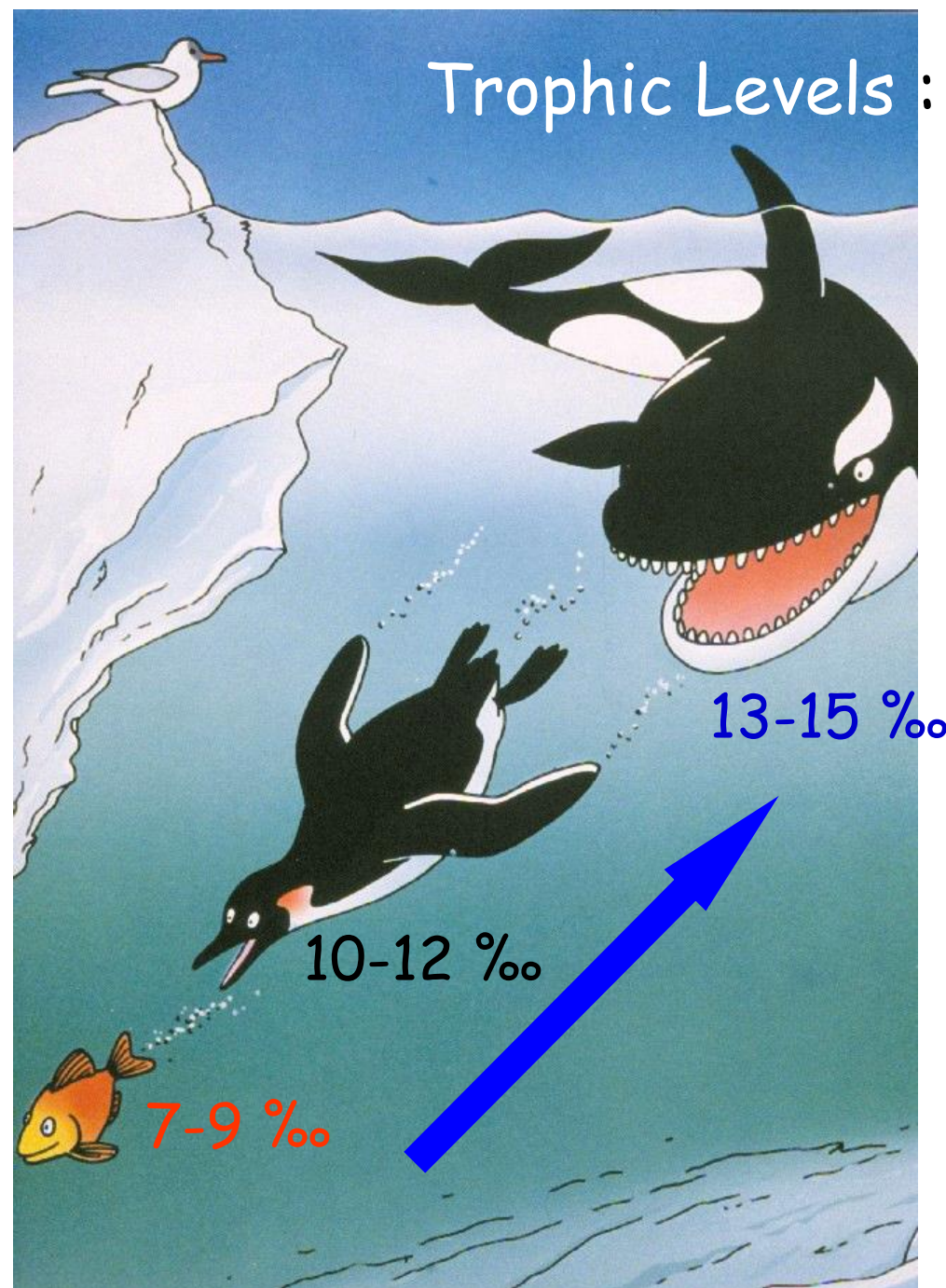
Sample ~ 5
million km^3
of the SO

Consume
3.3 million
fishes &
squids

Allow to identify
important SO
oceanographic &
ecological
habitats

Isotopy as a complementary tool
to investigate elephant seal
foraging ecology and
environnement la changes

Isotopy as a complementary tool for studying the ecology of elephant seals and environmental changes



Trophic Levels : Stable Isotopes

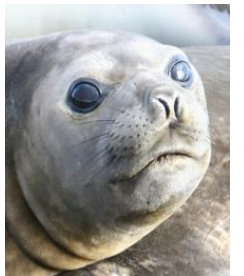
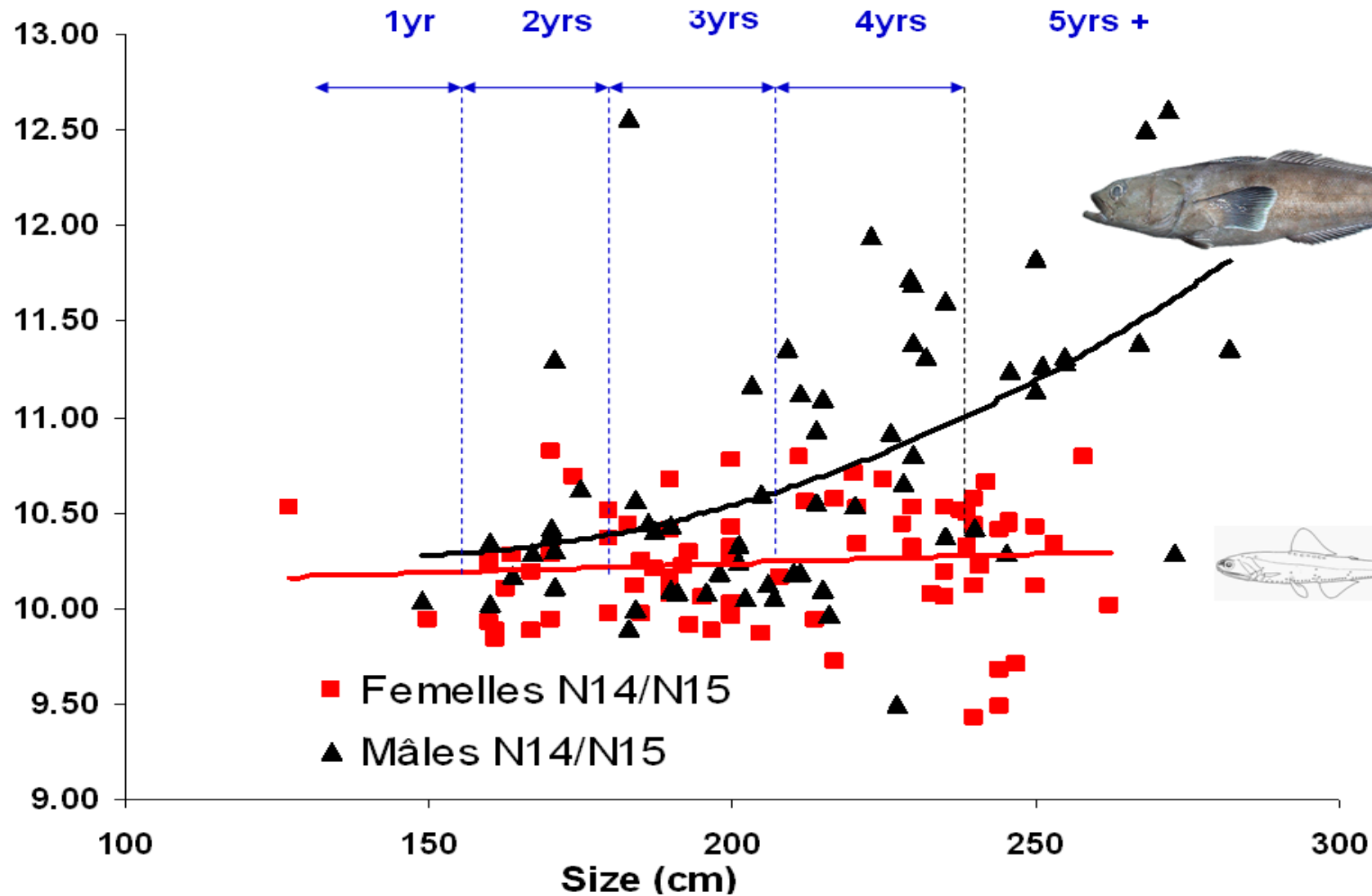
Nitrogen ($\delta_{15}\text{N}$) [15N/14N]

Enrichment per trophic level :

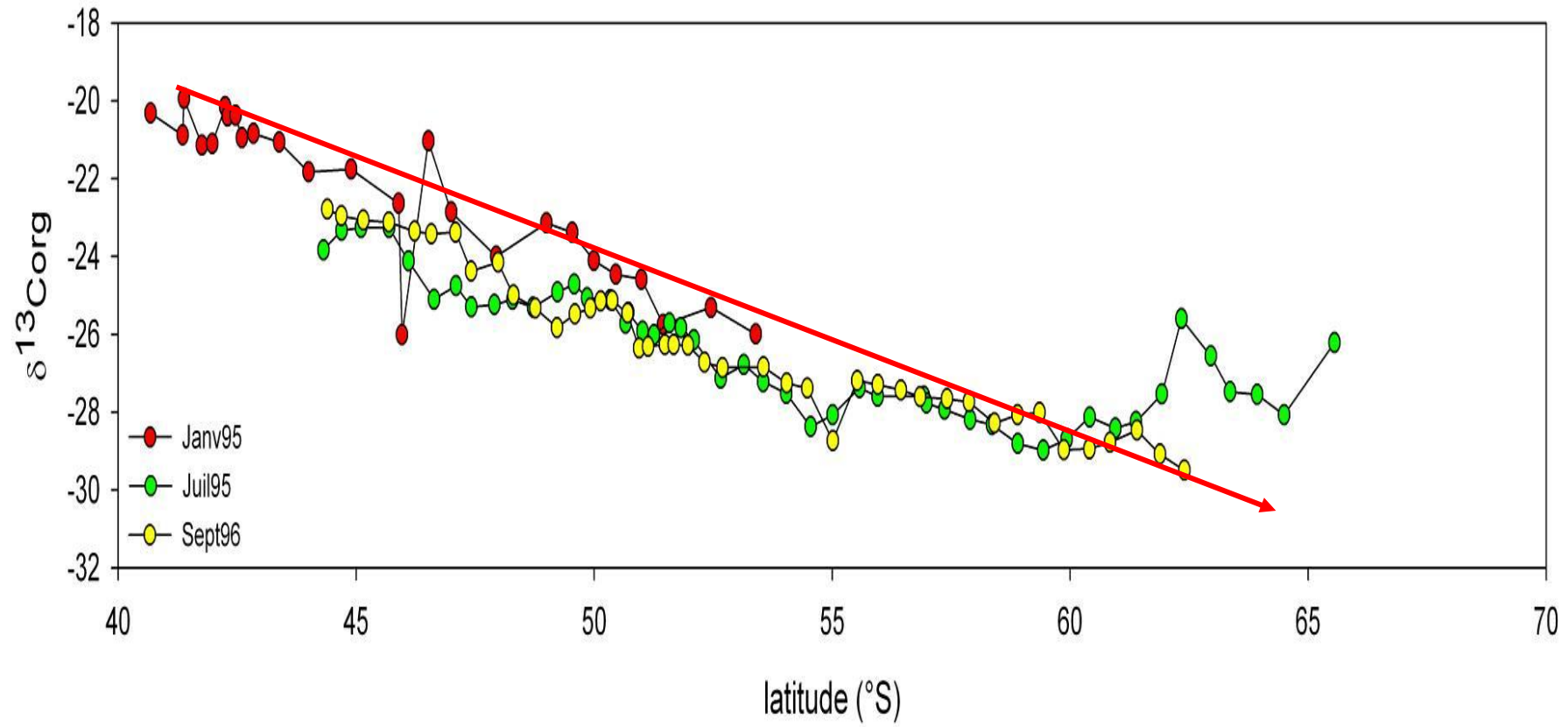
2-4 ‰

Results : Stable Isotopes $\delta N15$

Blood samples



$\delta^{13}\text{C}$ latitudinal gradient in the SO

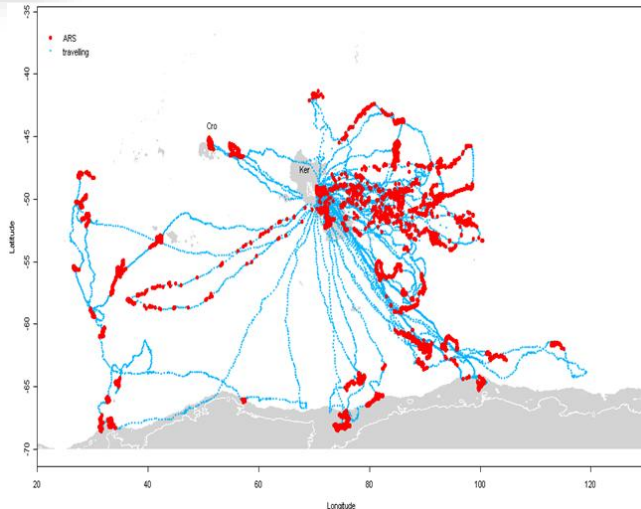


•Carbon stable isotopes

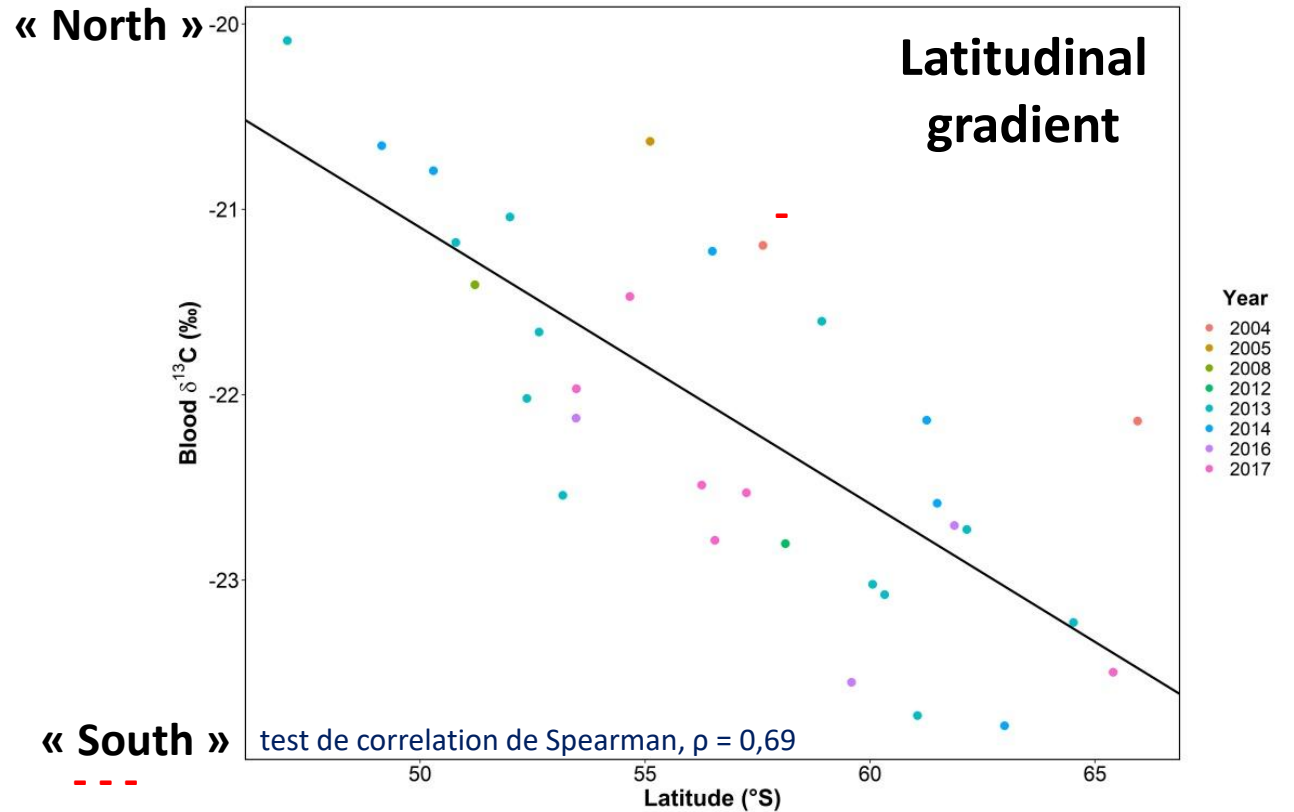
Tracks



- Mean Latitude of the May-July (4 mont before the return on-land for breeding of the foraging zonesd'alimentation



« North »



« South »

Spearman correlation test,
 $\rho = 0,69$, $p\text{-value} < 0,0001$

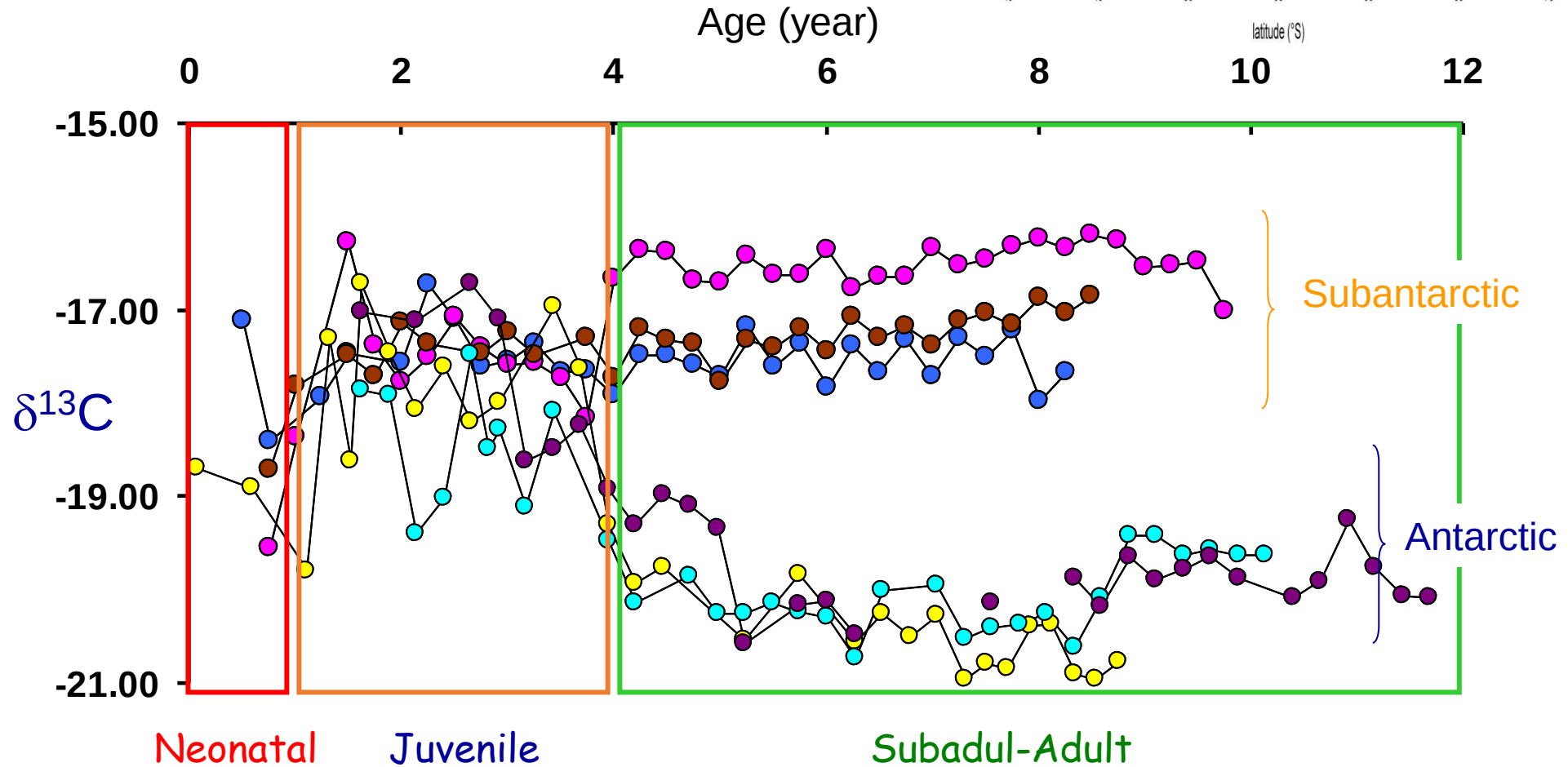
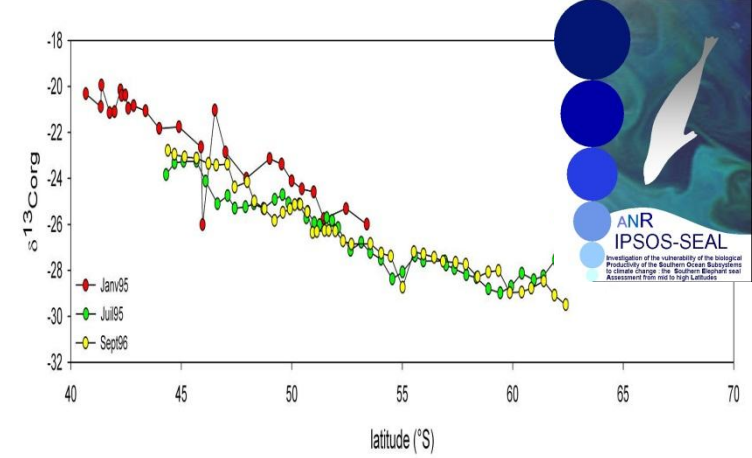
➤ Teeth crossection :

ISEM-Spectrometer



Ontogeny and Behavioural plasticity

Teeth : Archive Tissue



δN_{15}

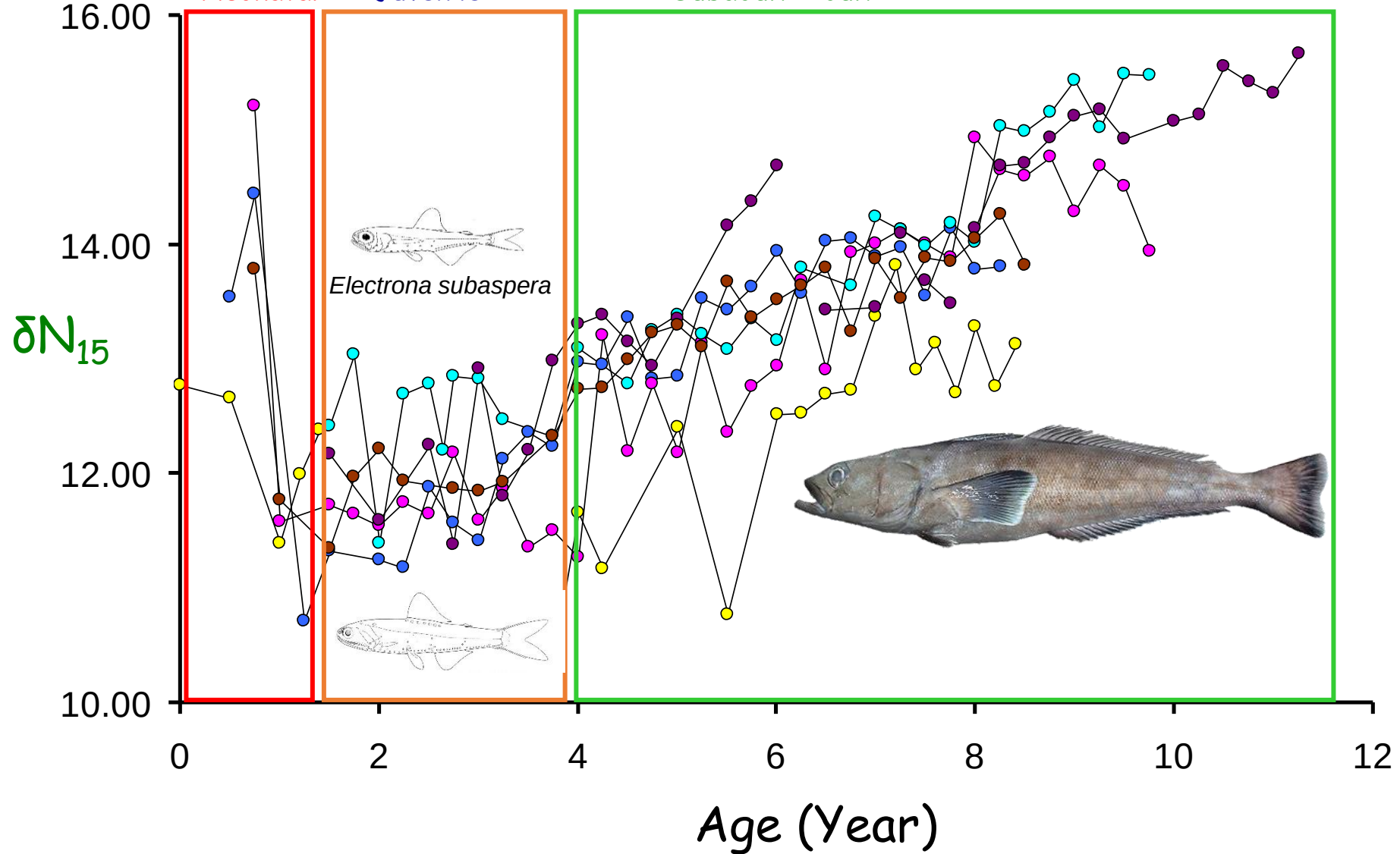


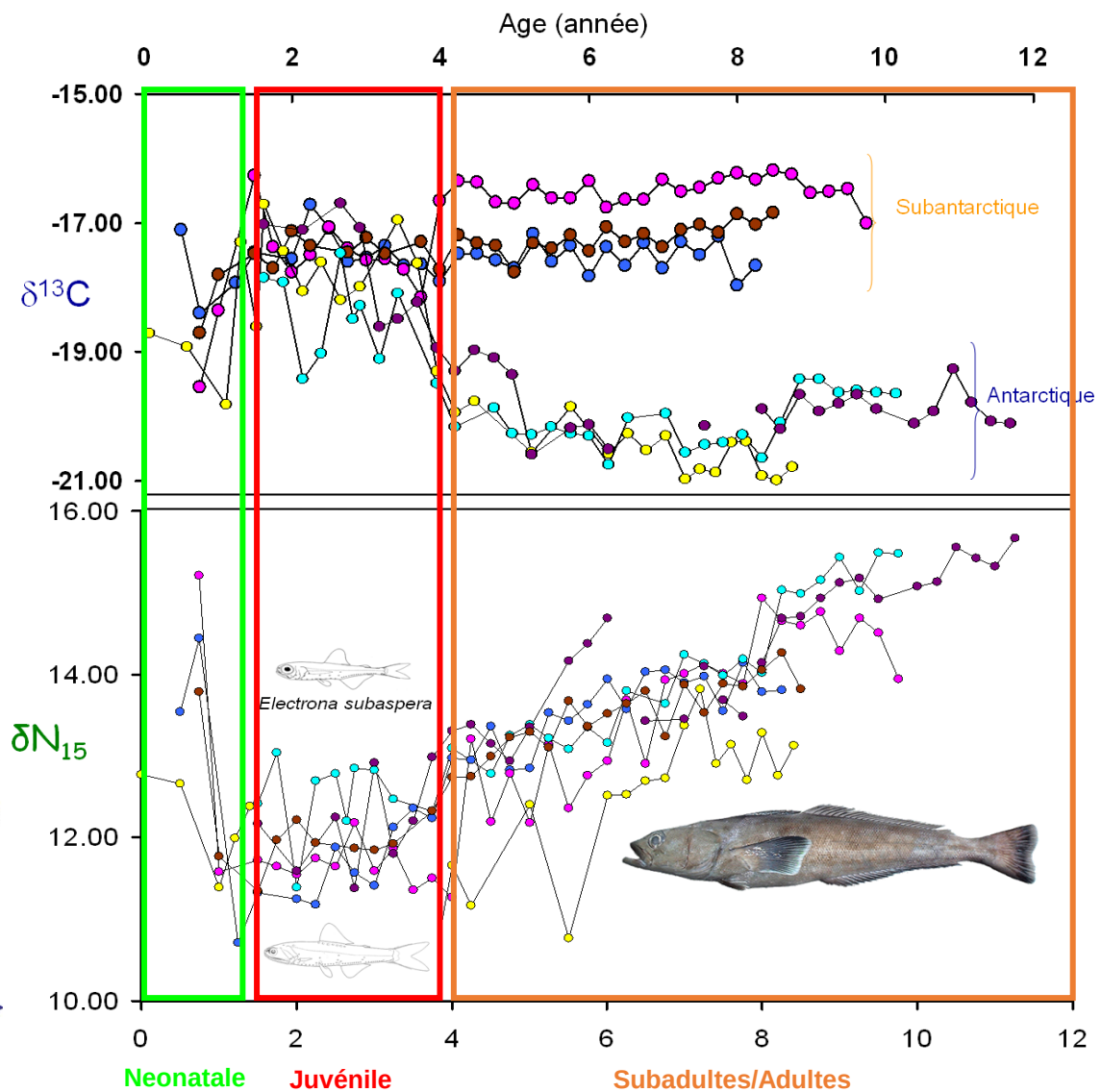
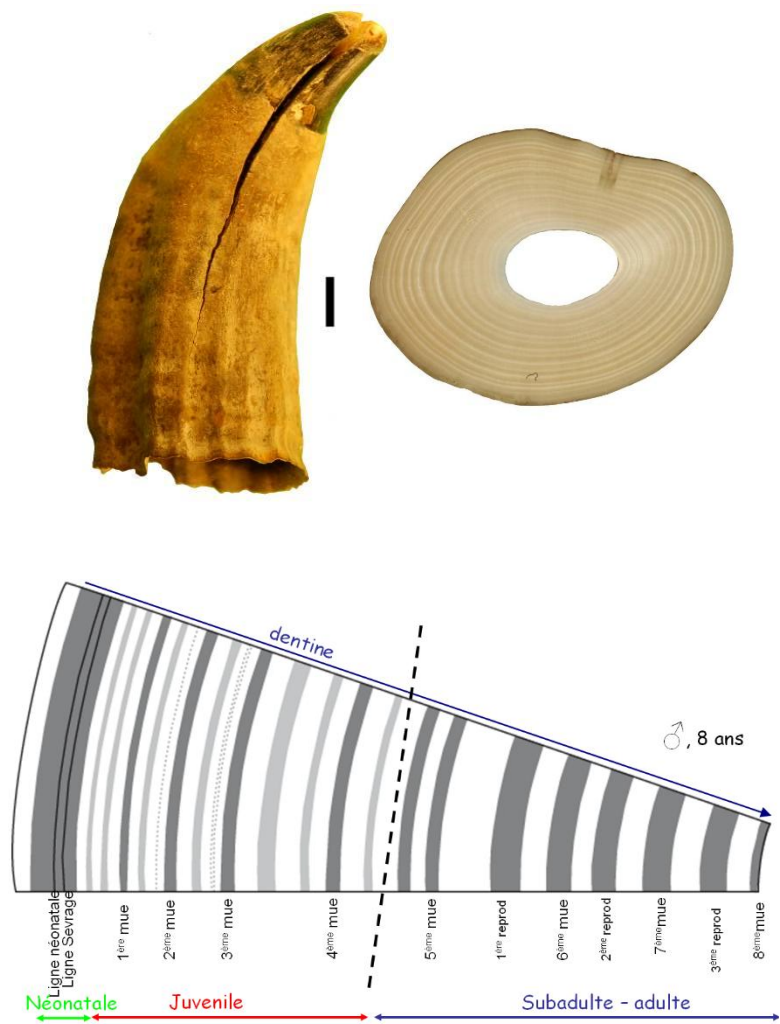
Neonatal

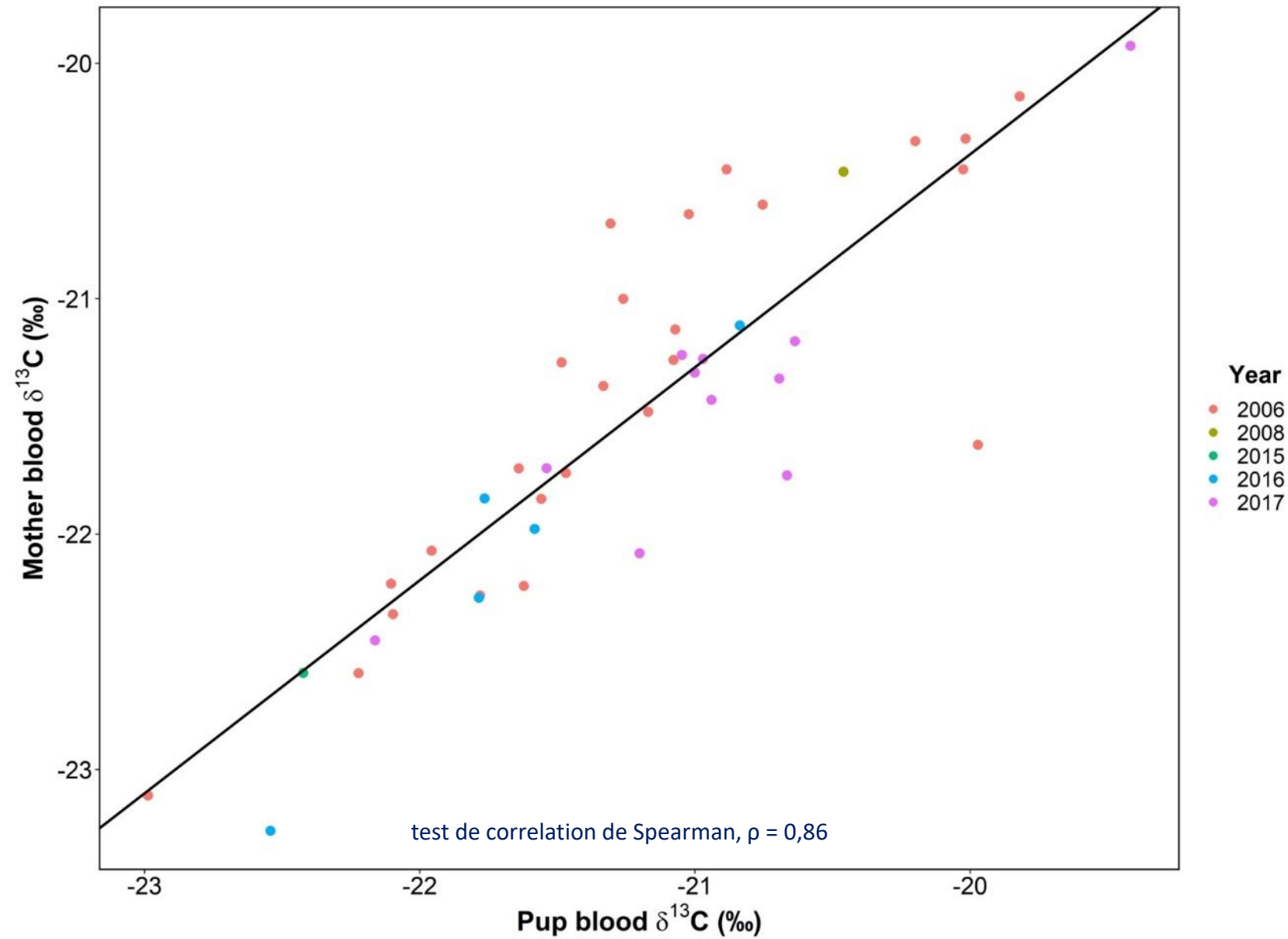
Juvenile

Subadult-Adult

Teeth : Males

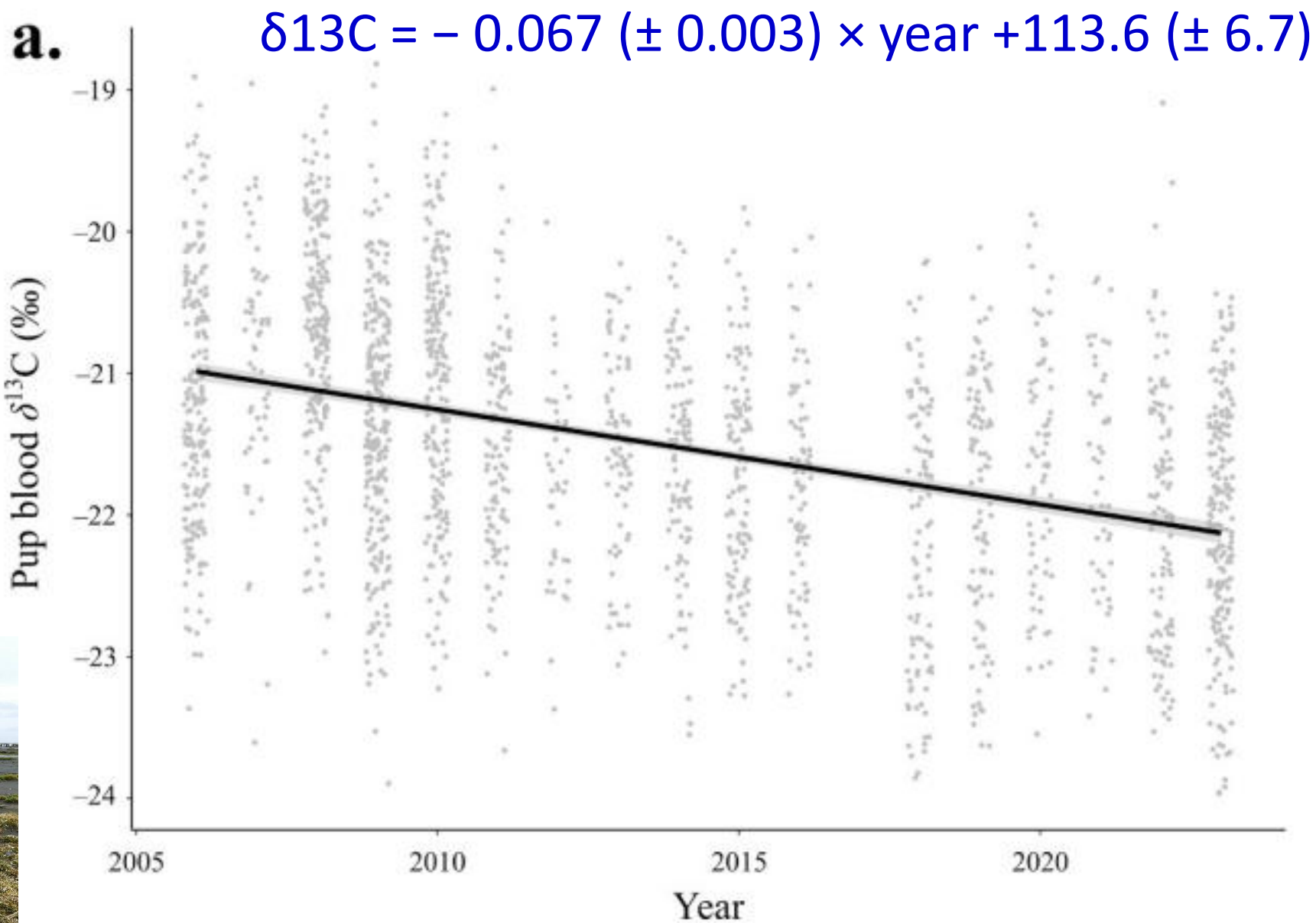


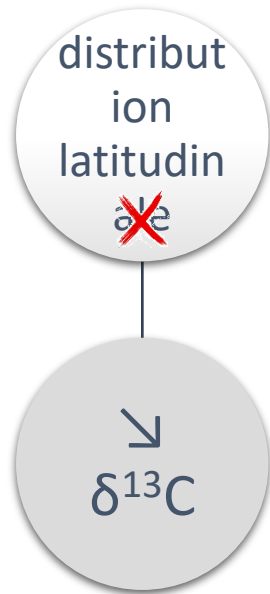




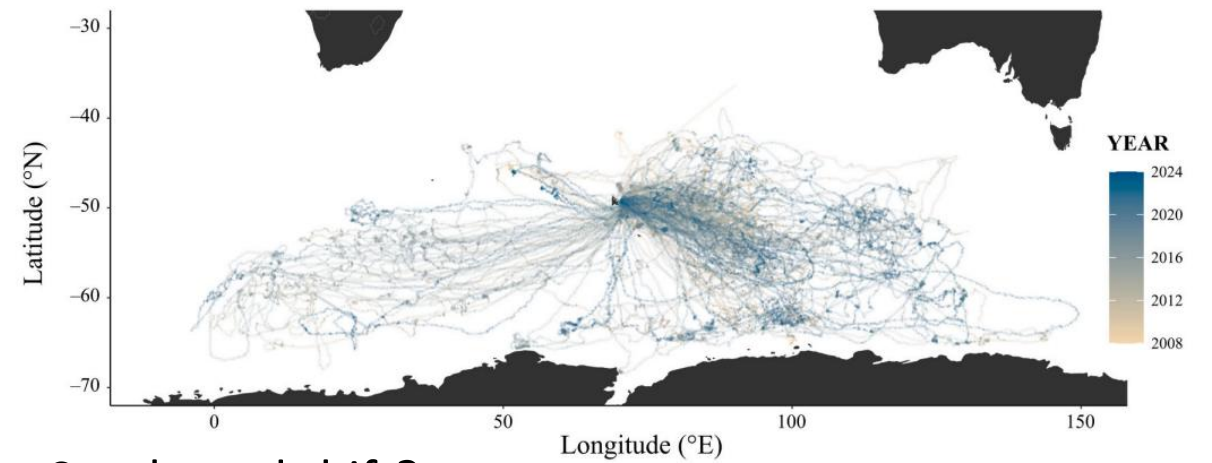


Nicolas
Séon





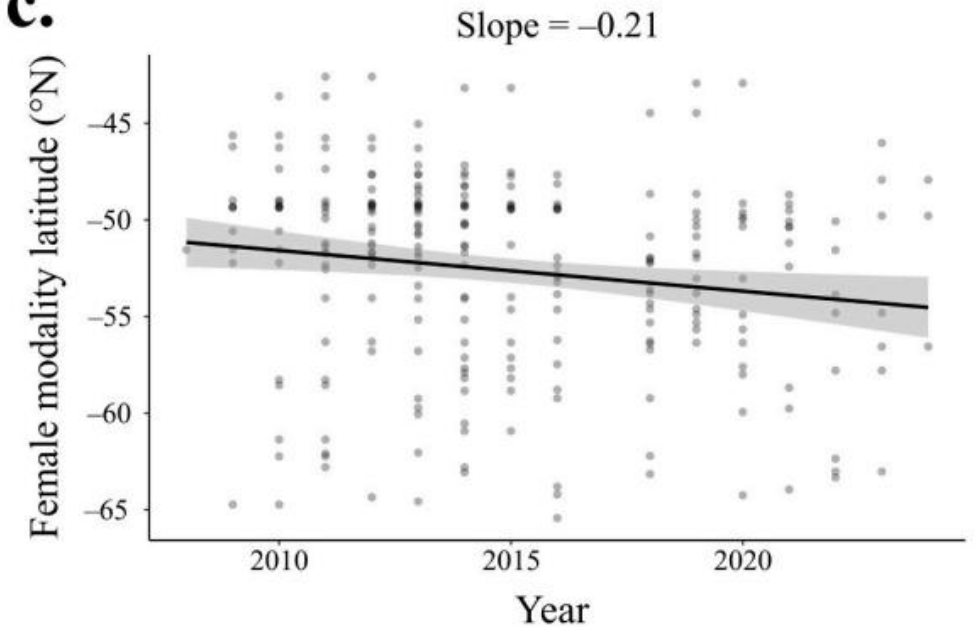
a.



• Southward shift?

3° southward shift → -0,45‰

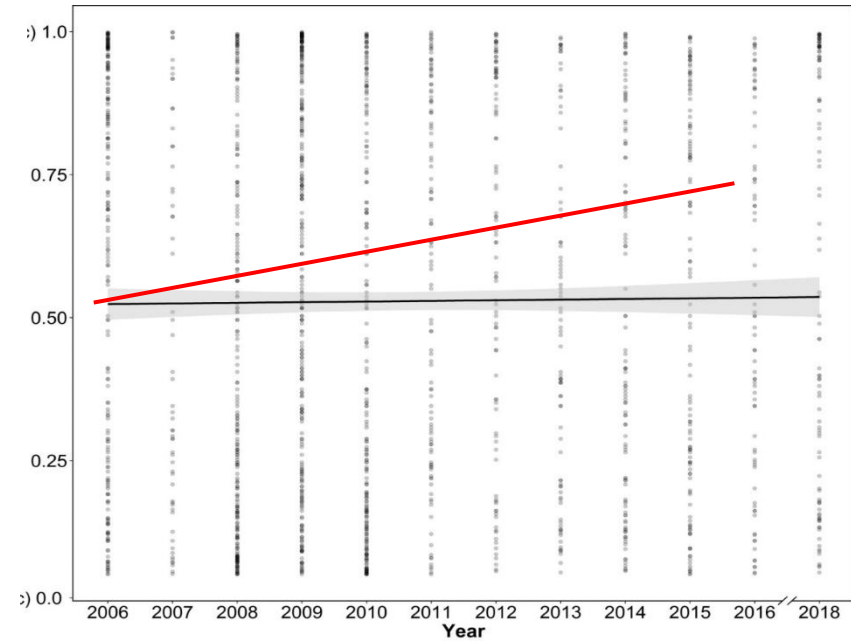
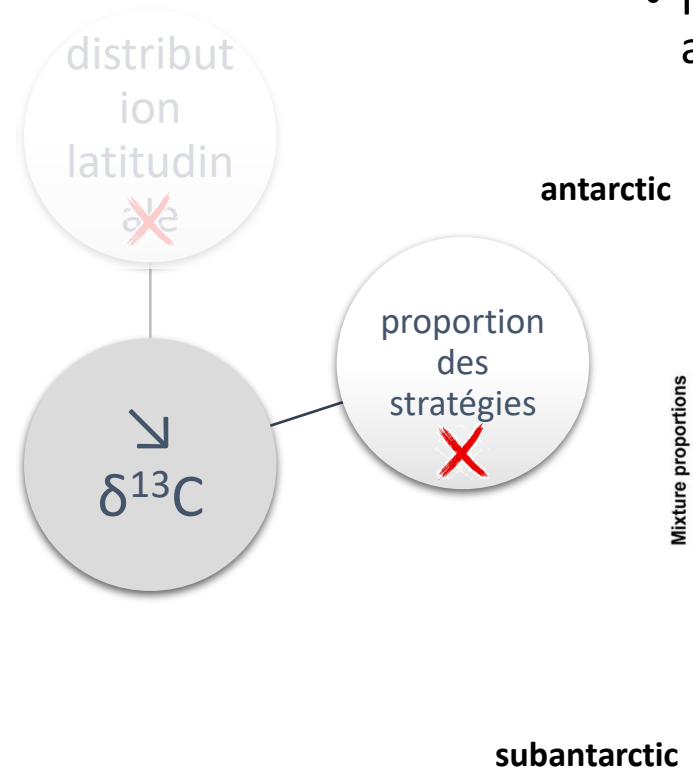
c.

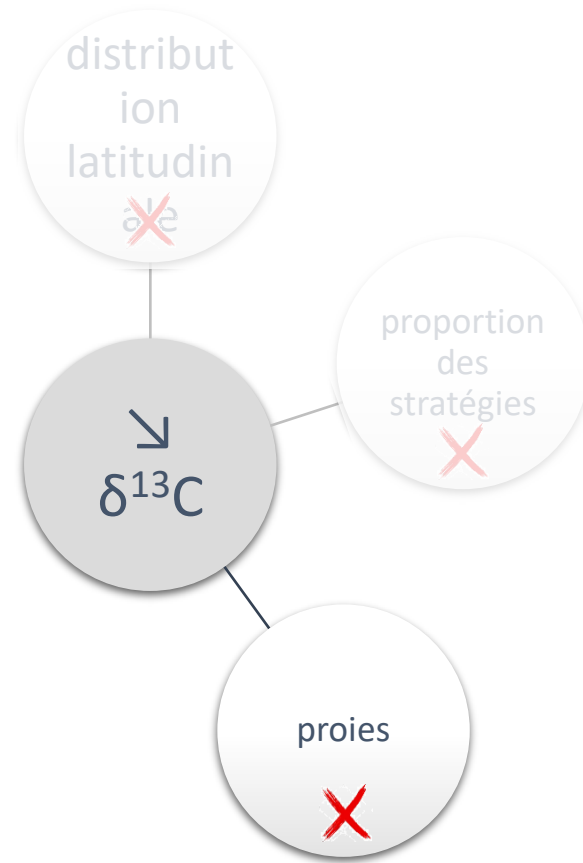


→ $\delta^{13}\text{C} \text{ (♀)} = -1,4 \text{ ‰}$

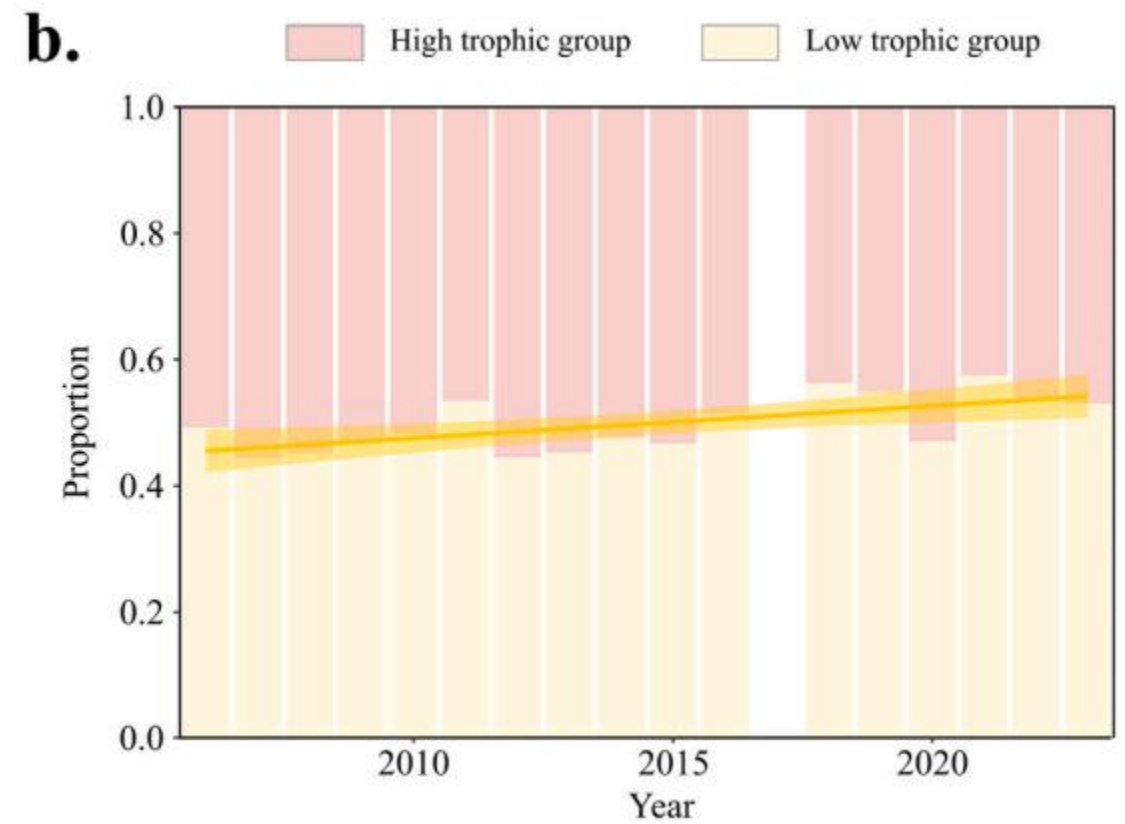
→ ~~déplacement 1036 km (9,33°)~~

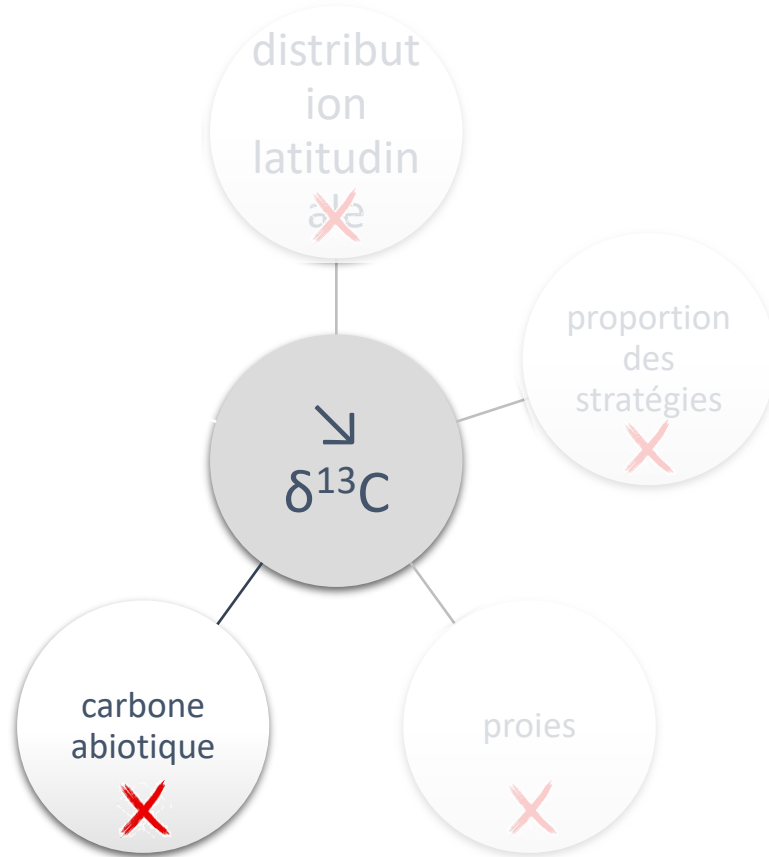
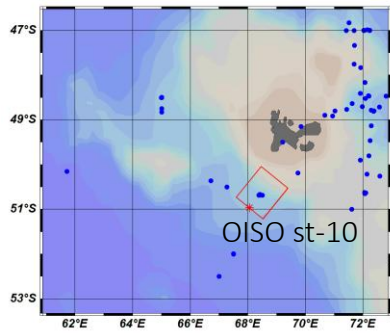
- Increasing number of females foraging in antarctica versus in the subantarctic waters ?



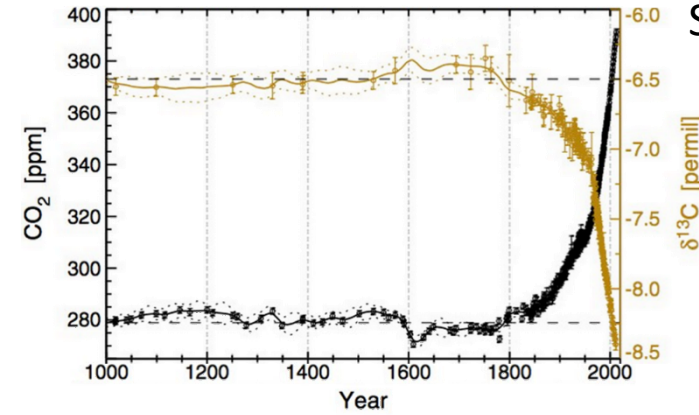


- Diet change ?





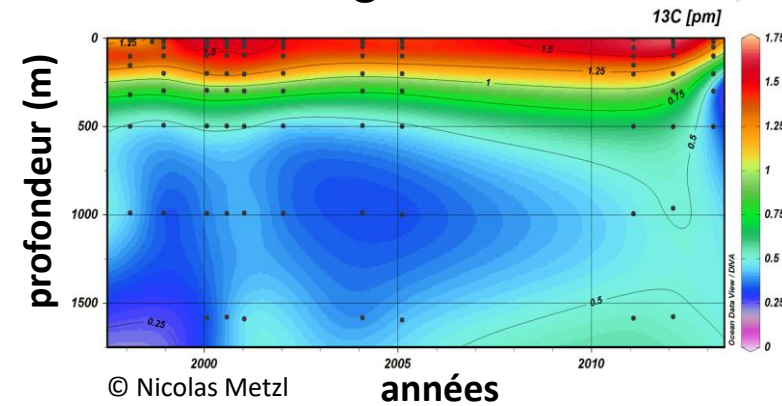
• SUESS effect? ✗

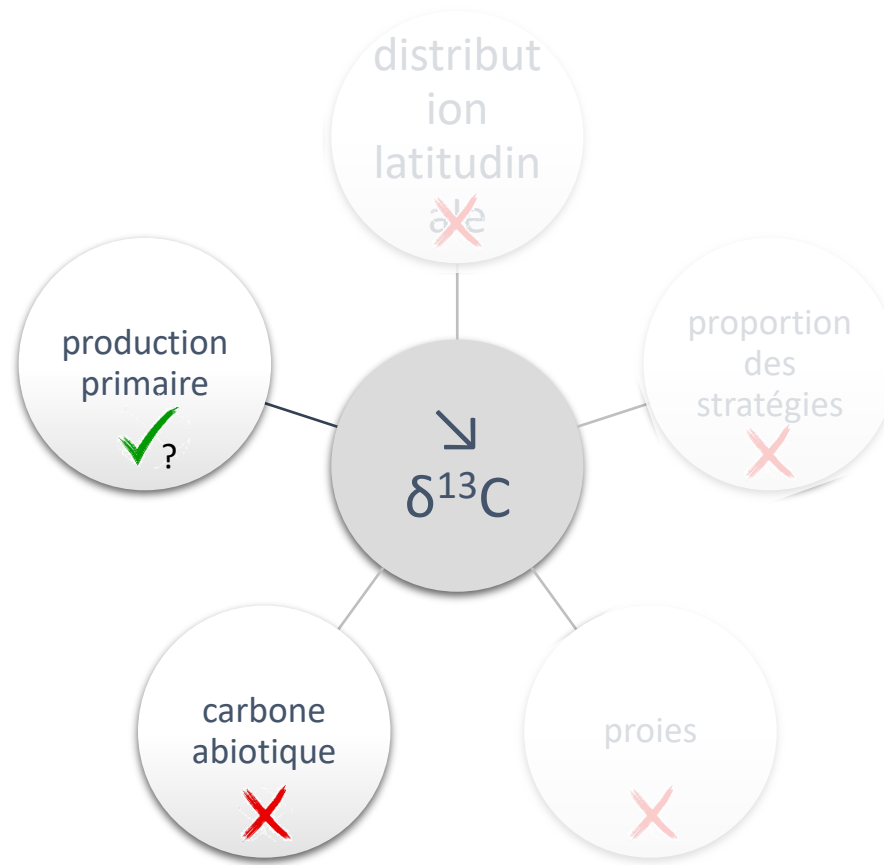


Southern Ocean :
-0,01‰ /decade

This study :
-0.9‰ /decade

• Dissolved inorganic carbon ? ✗





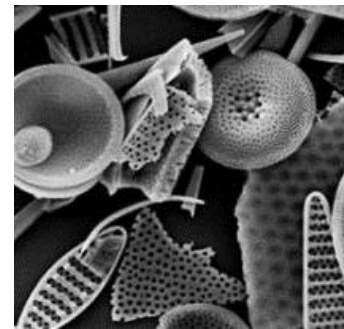


Deuser, 1970

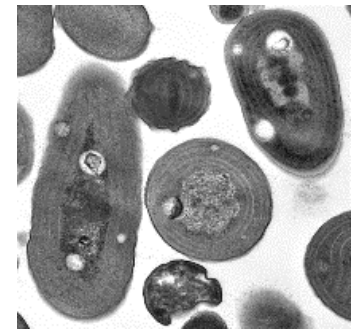
- Primary production ?

- The incorporation of $\delta^{13}\text{C}$ depends:

of the ratio surface/volume of the cell



$\delta^{13}\text{C} >$



Amino acid stable isotope composition

BULK SIA

Bulk

Env./Baseline + Trophic/Metab.

Bulk stable isotope values alone
do not allow the distinction of
the respective effects

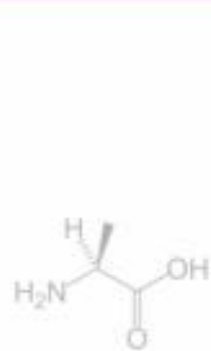


Nicolas
Séon

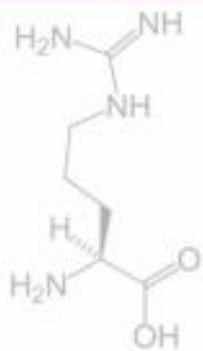


Auriane
Bouillot

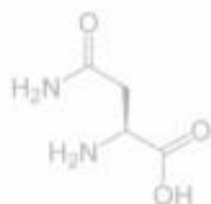




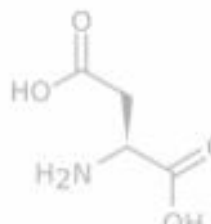
L-Alanine



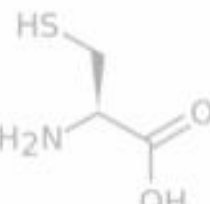
L-Arginine



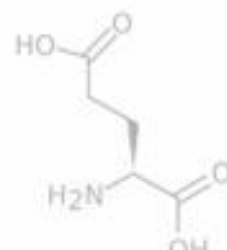
L-Asparagine



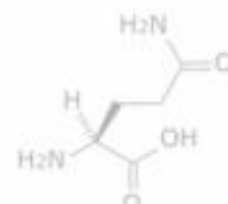
Acide
L-aspartique



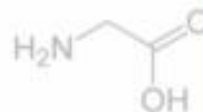
L-Cystéine



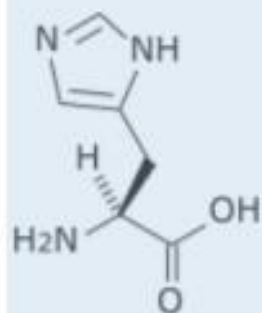
Acide
L-glutamique



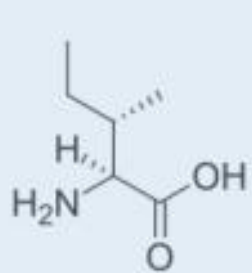
L-Glutamine



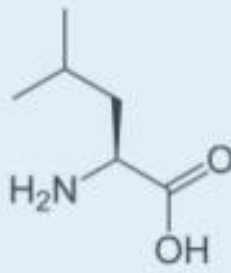
Glycine



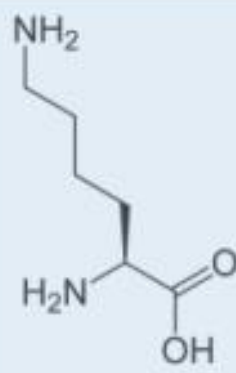
L-Histidine



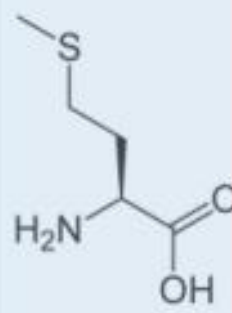
L-Isoleucine



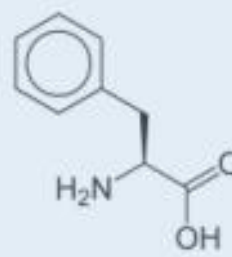
L-Leucine



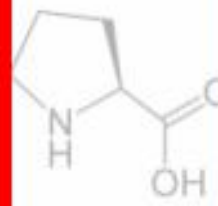
L-Lysine



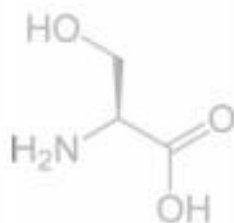
L-Méthionine



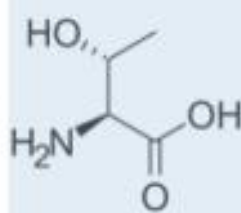
L-Phénylalanine



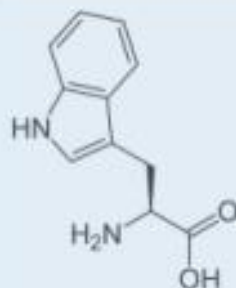
L-Proline



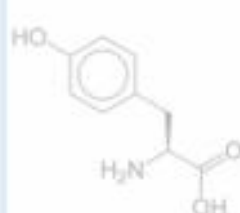
L-Sérine



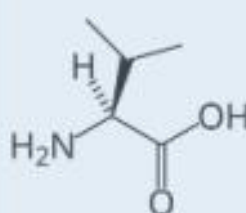
L-Thréonine



L-Tryptophane



L-Tyrosine



L-Valine

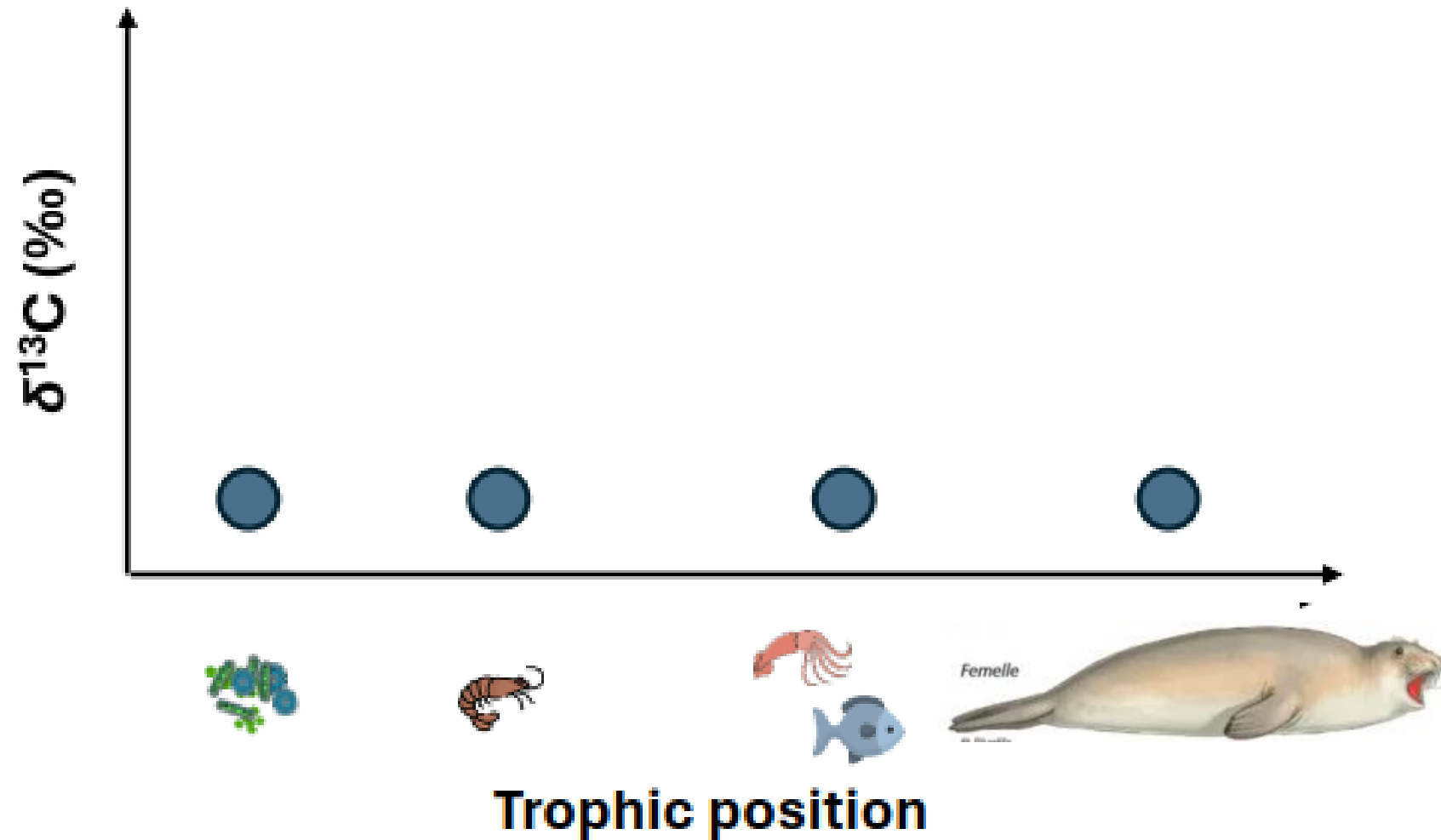
traceur de
référence de la
base



Phenylalanine



Proline, Glu. acid

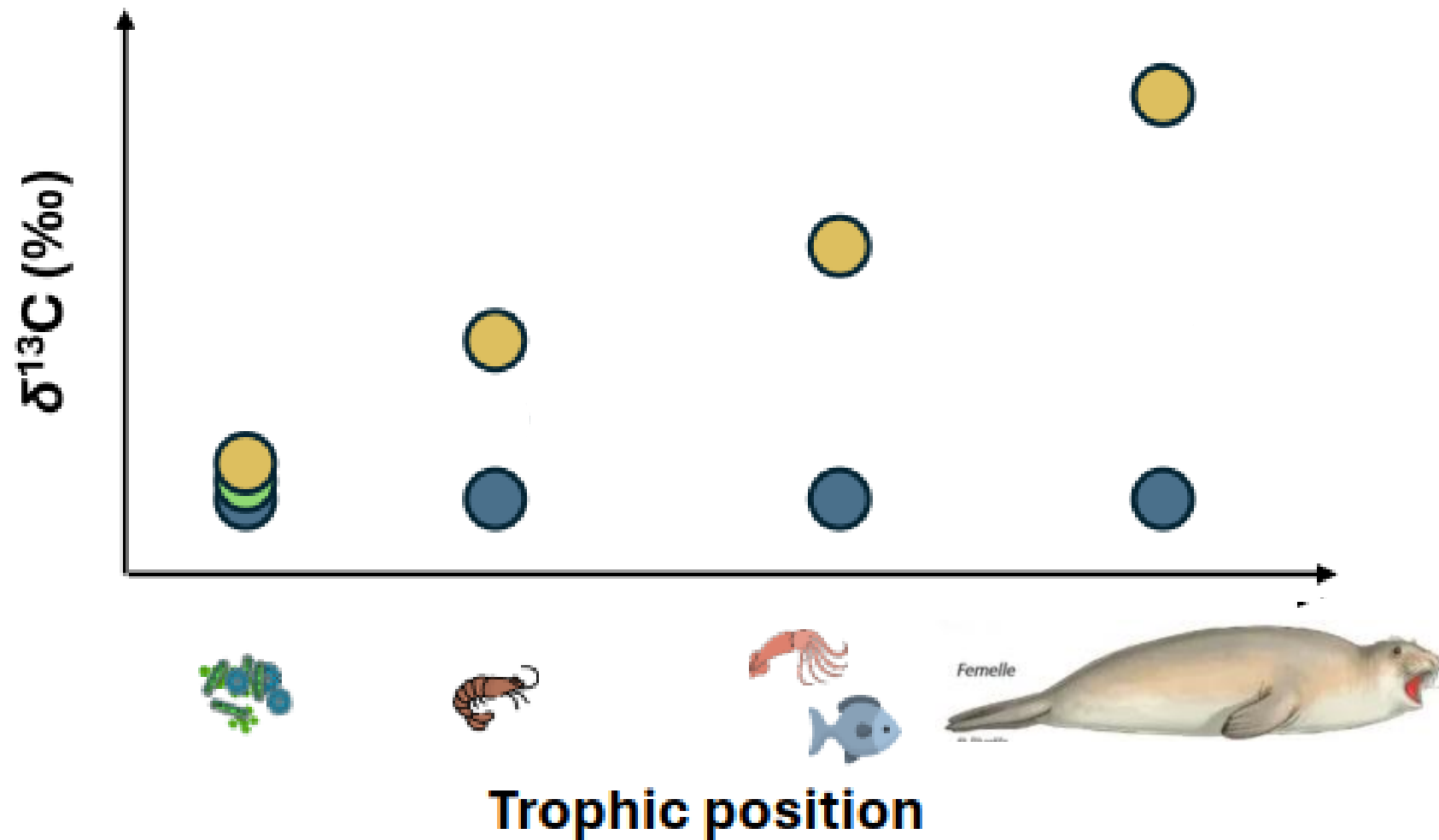




Phenylalanine



Proline, Glu. acid



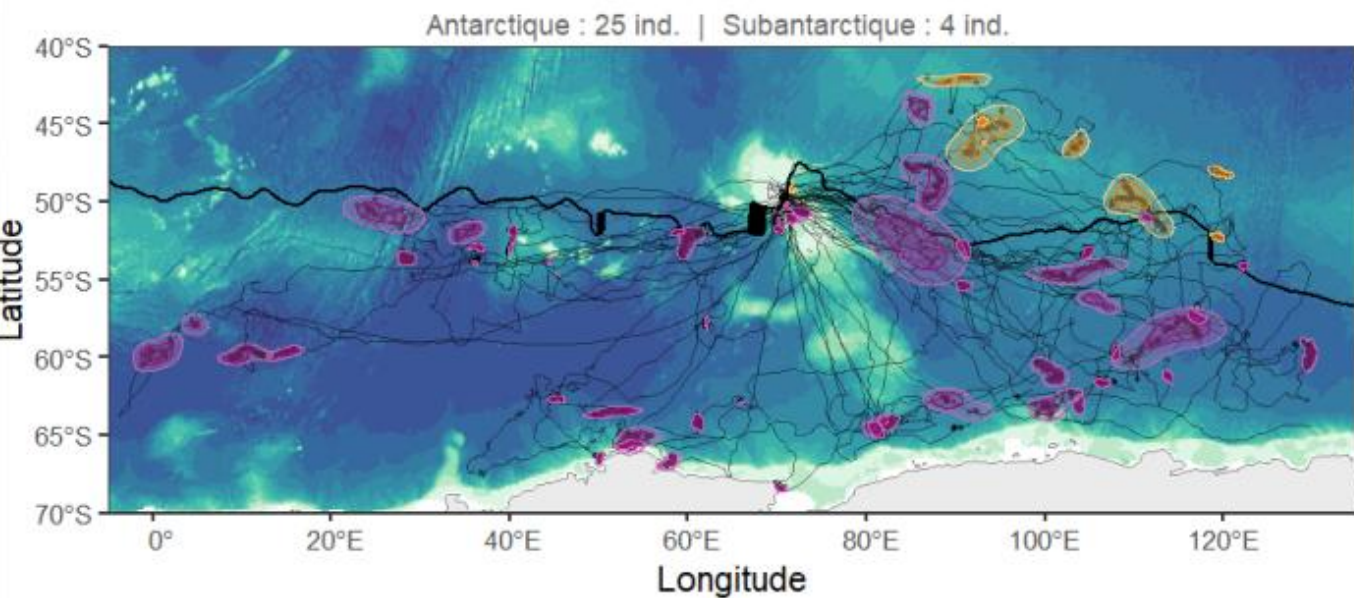


29 Éléphant de mer du Sud

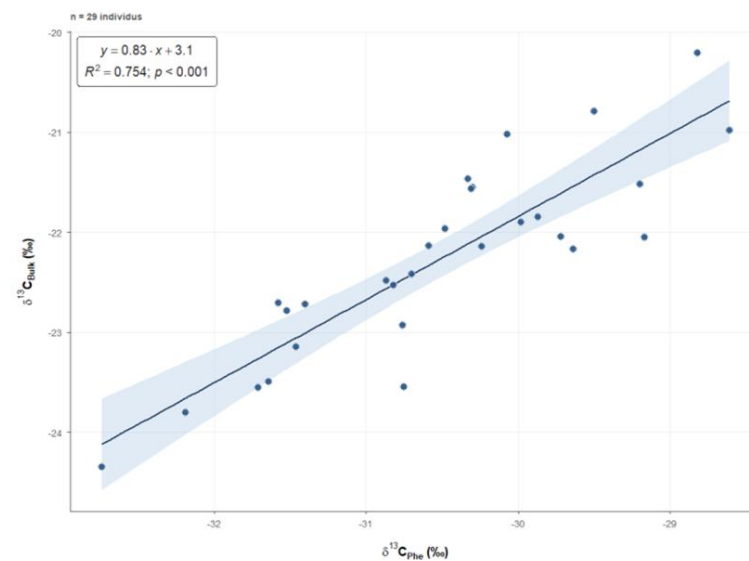
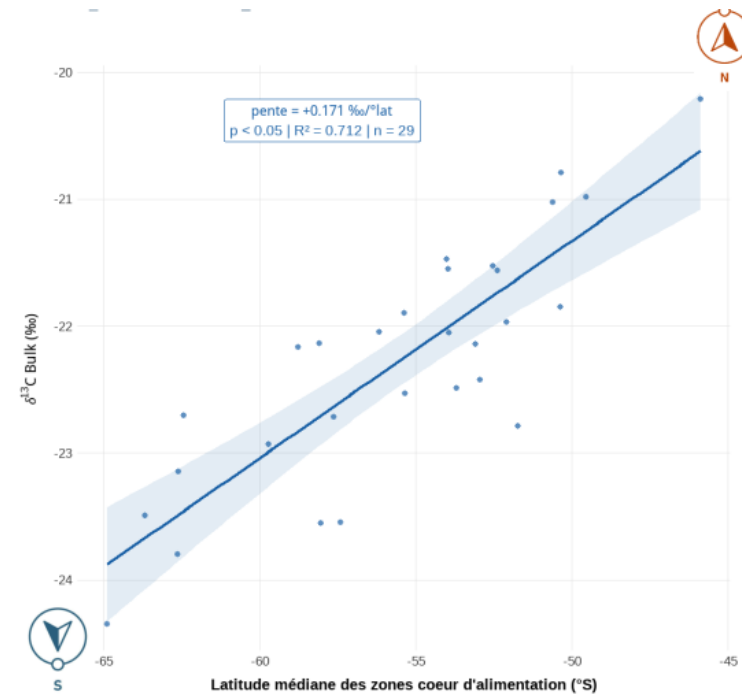


(2014-2023)

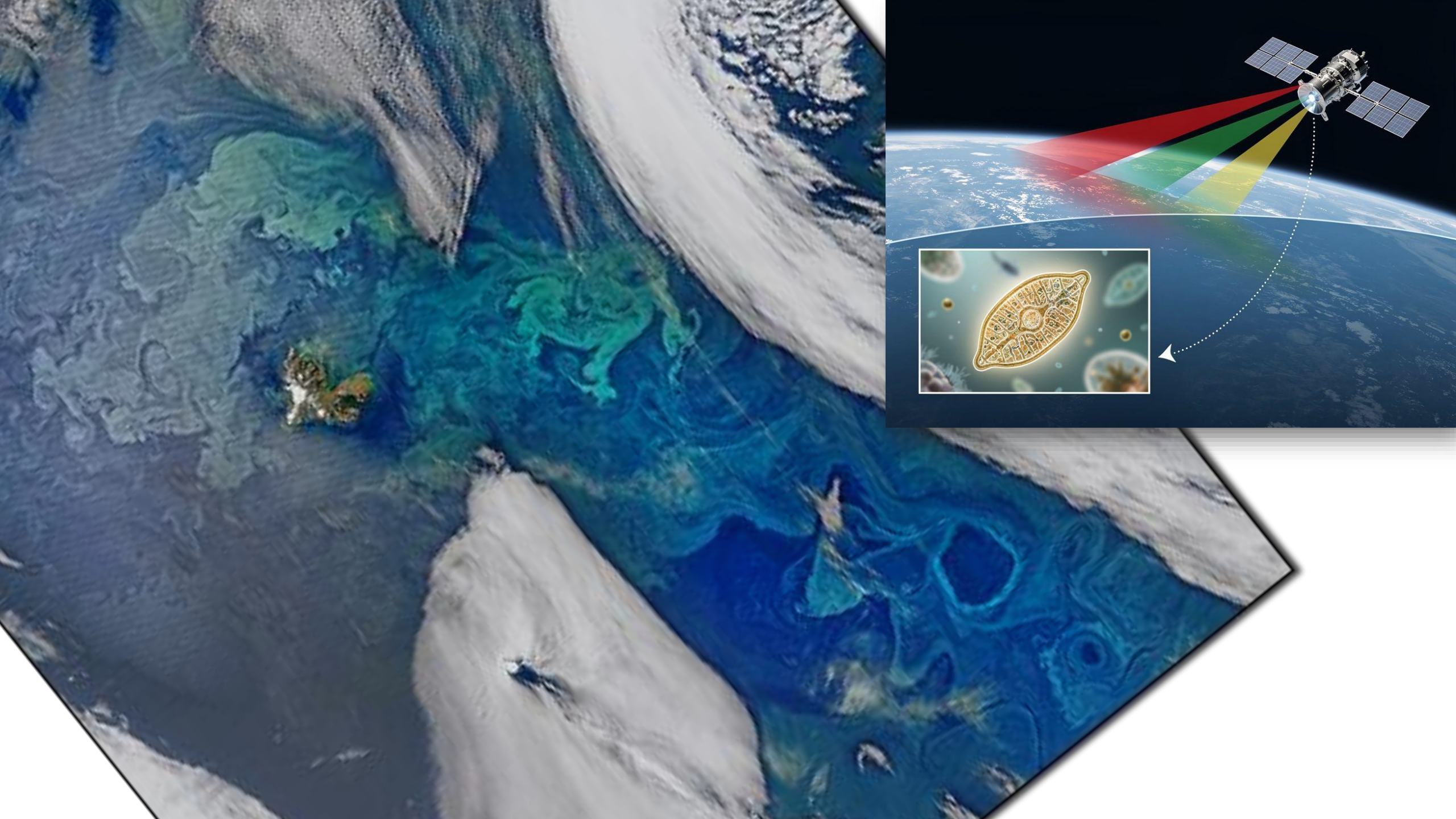
- $\delta^{13}\text{C}$ AA
- Trajectoires (Balises Argos)
- $\delta^{13}\text{C}$ Bulk (Ensemble des femelles) (n=420)

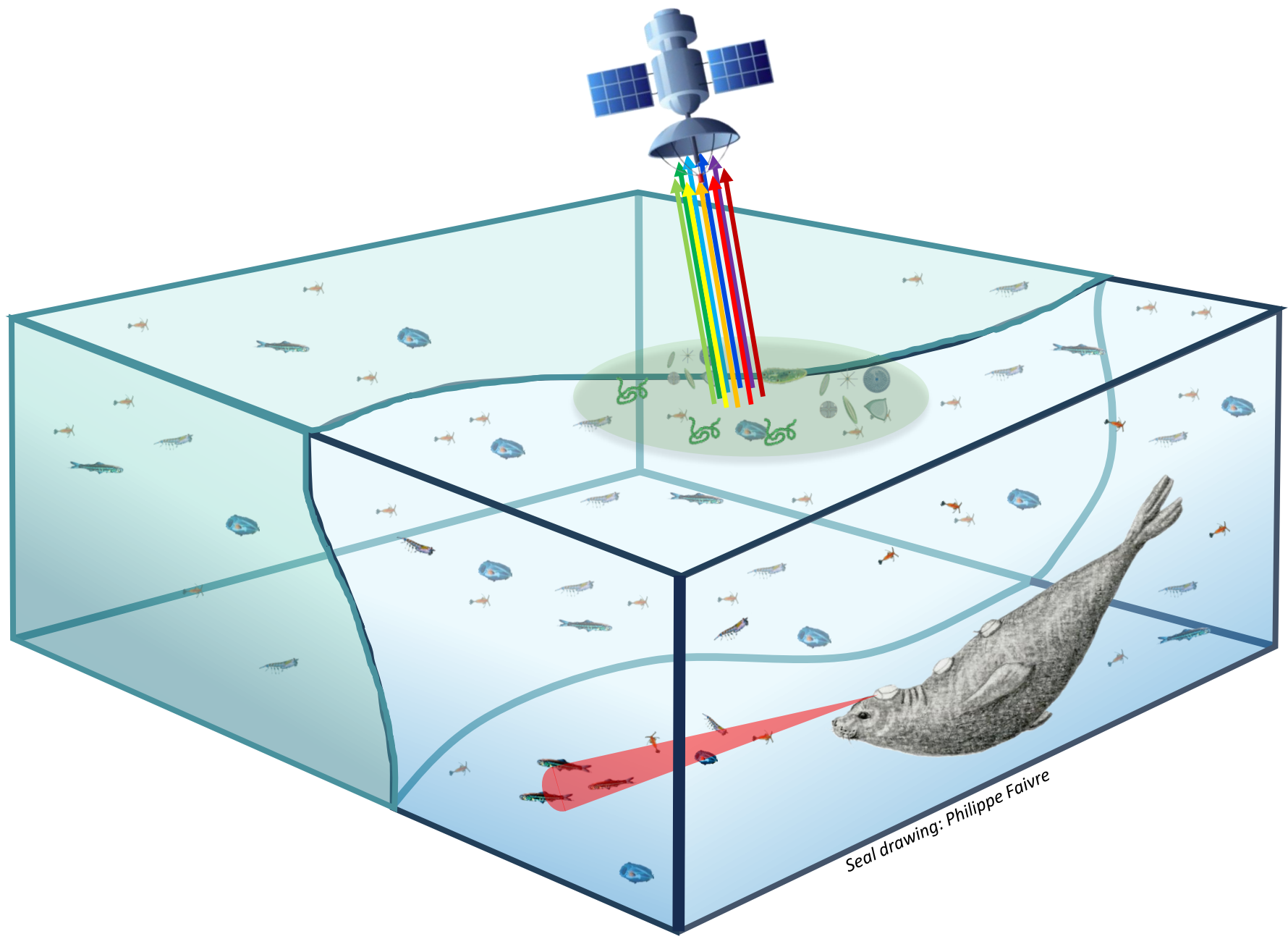


Centroïde Kernel 50% ● Antarctique ● Subantarctique



Forte corrélation au niveau individuel → le Bulk est prédit par la Phe avec $R^2 = 0,75$

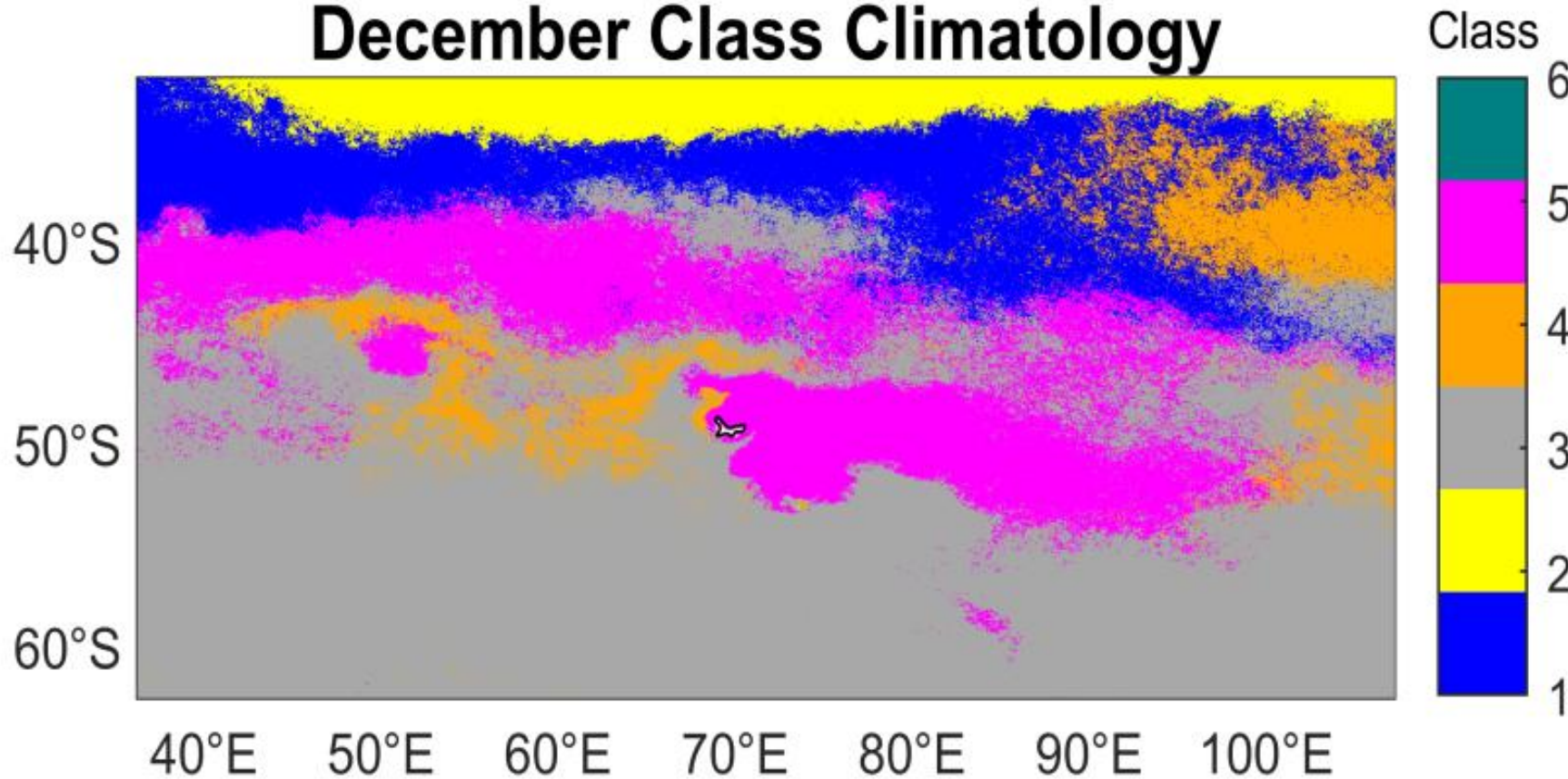




Seal drawing: Philippe Faivre

Classified Southern Ocean (SO) waters into 6 classes based on patterns in satellite-derived bio-optical products

December Class Climatology



Diatoms



Collaboration: Roy El Hourany & Ziad Sari el Dine,
Laboratoire d'Océanologie et Géoscience

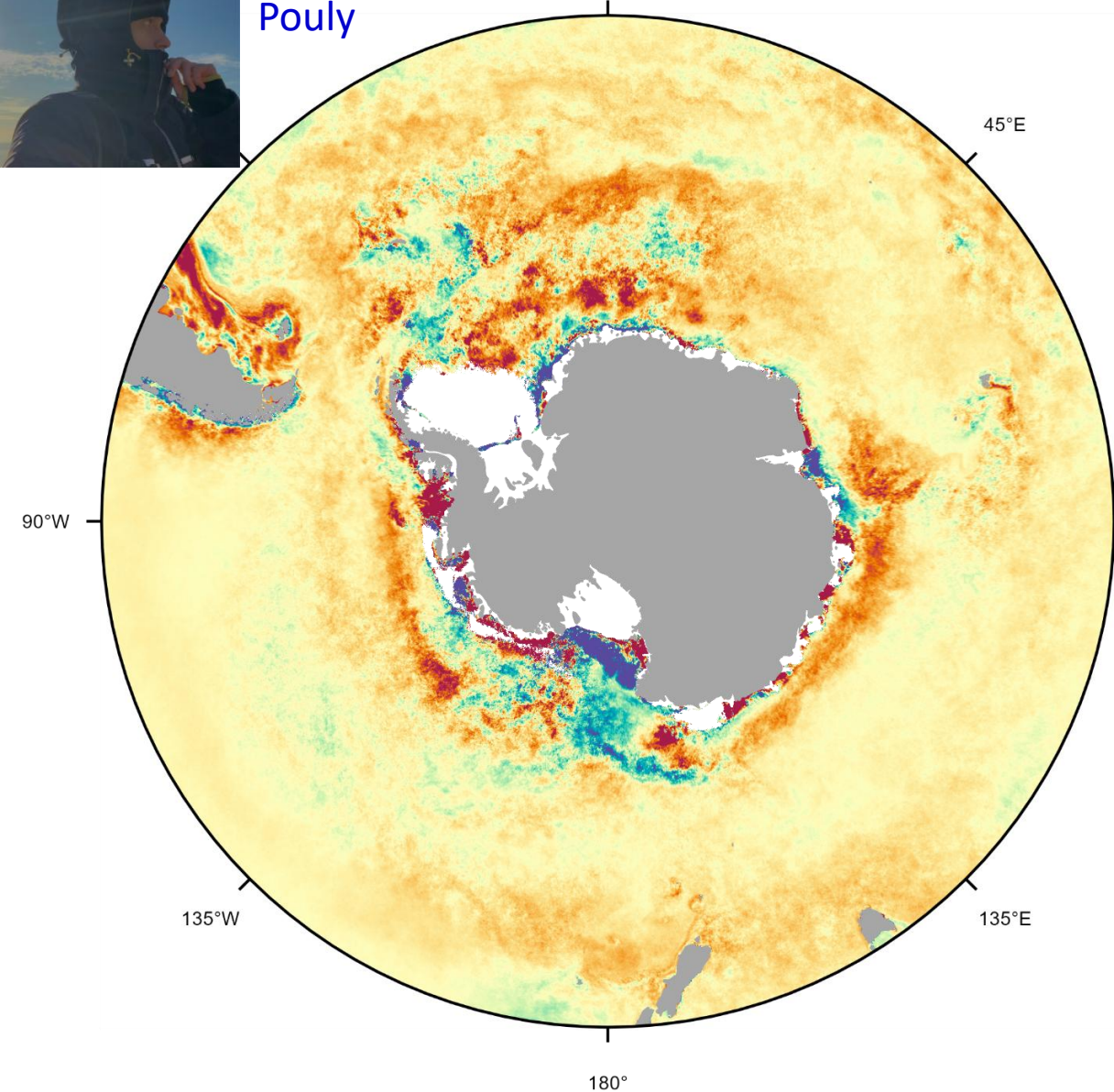


Weekly PCA Correlation		
	Spearman Classes vs. PCA	Spearman Classes vs. Normalized PCA
Class 1	-0.2305	-0.2466
Class 2	0.0354	0.3873
Class 3	0.1698	0.0120
Class 4	-0.1183	-0.1801
Class 5	0.3943	0.4815
Class 6	-0.2750	-0.2724



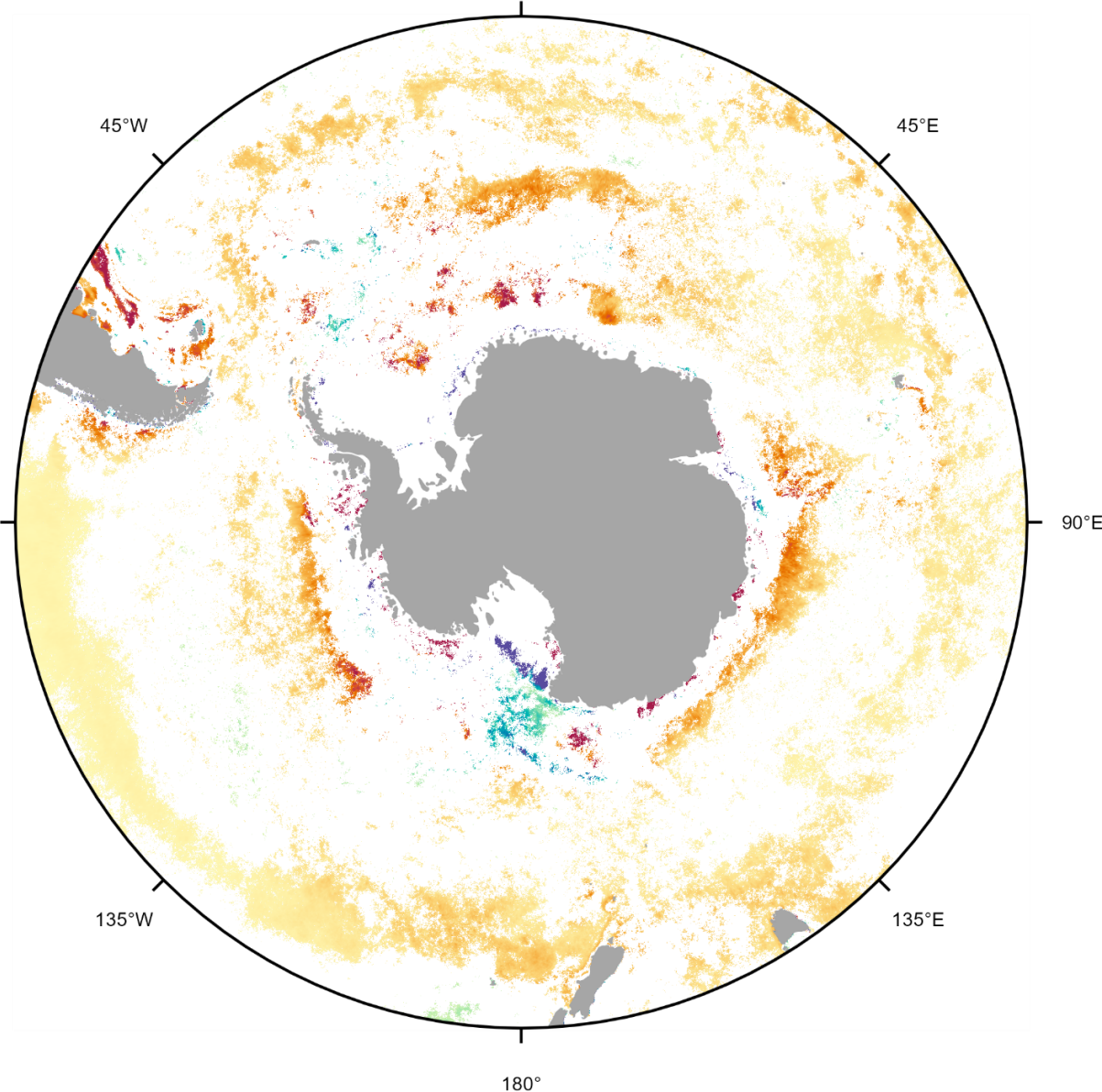
Mathias
Pouly

Chl_a Annual Trend Southern Ocean: ESA-Climate-Change Initiative product (4 x 4km, Daily)



Slope (yr⁻¹)

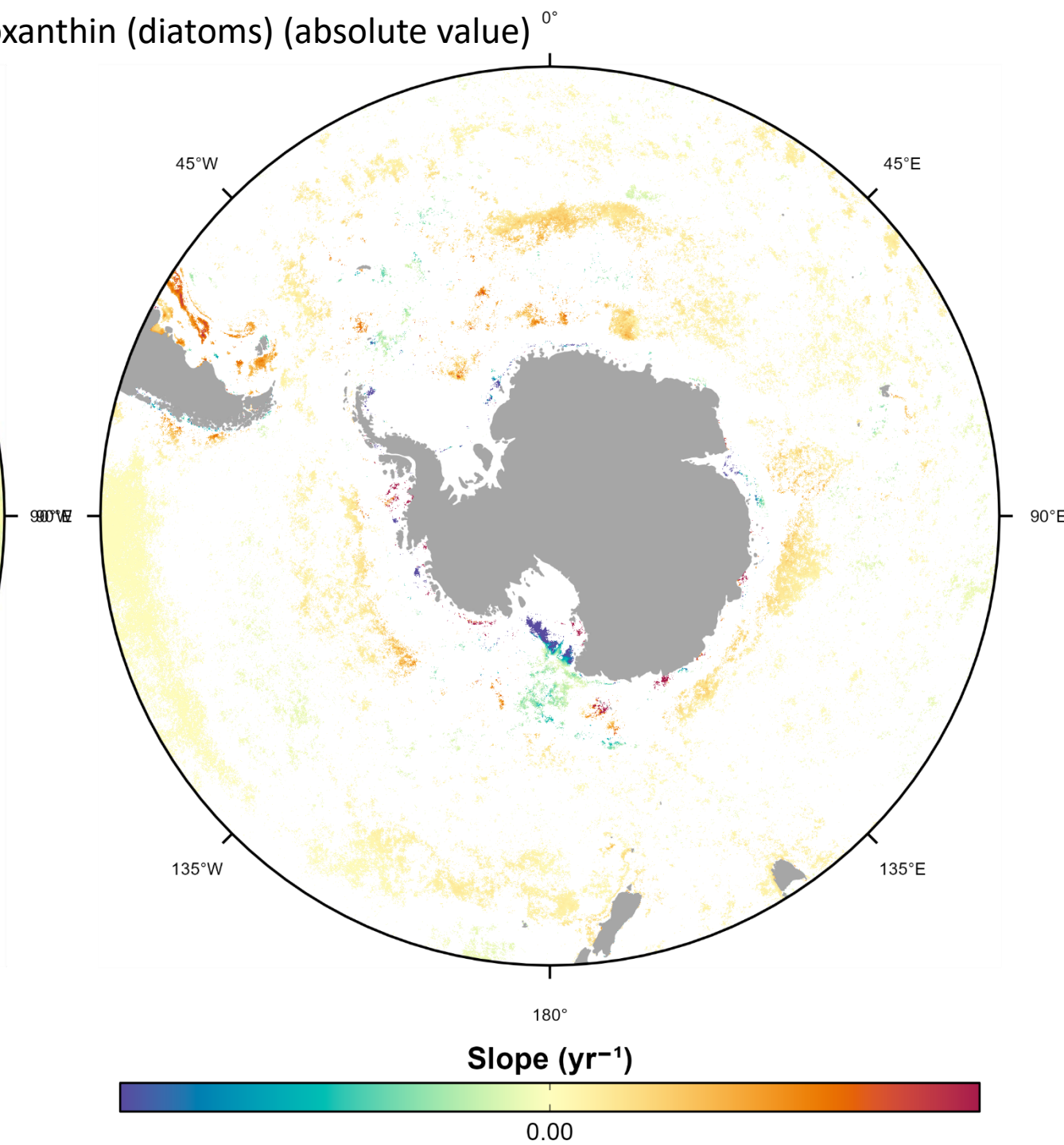
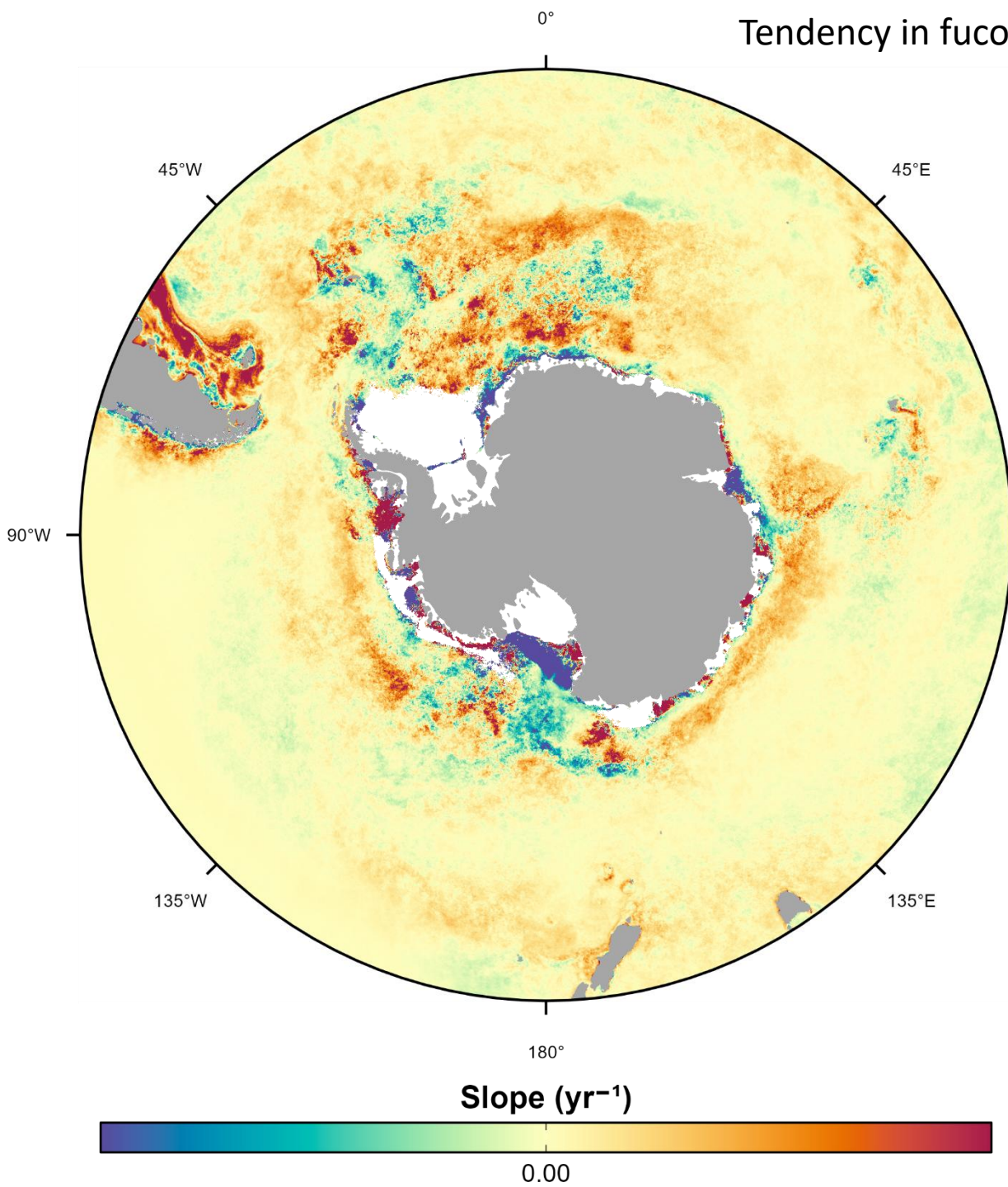
0.00



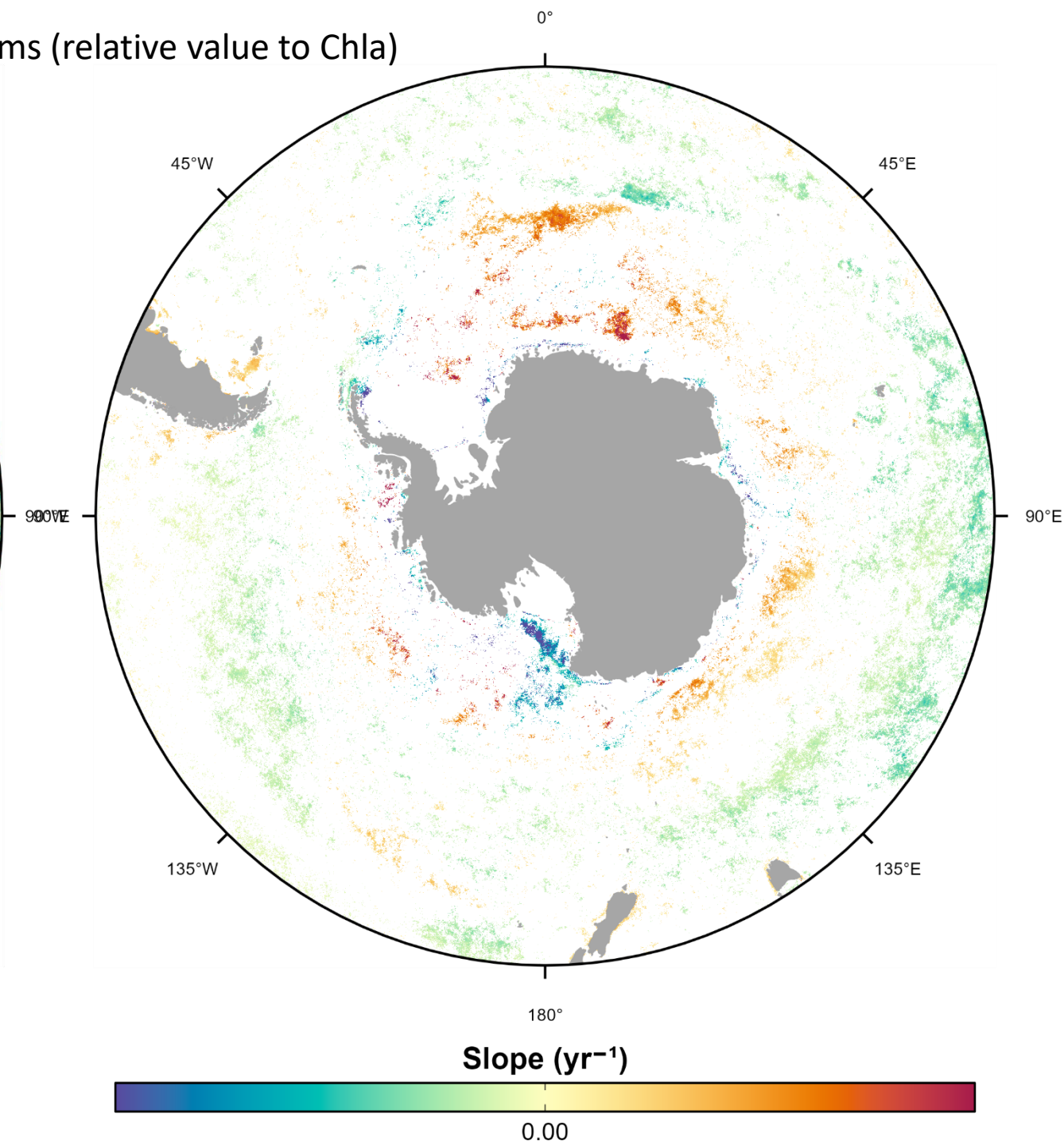
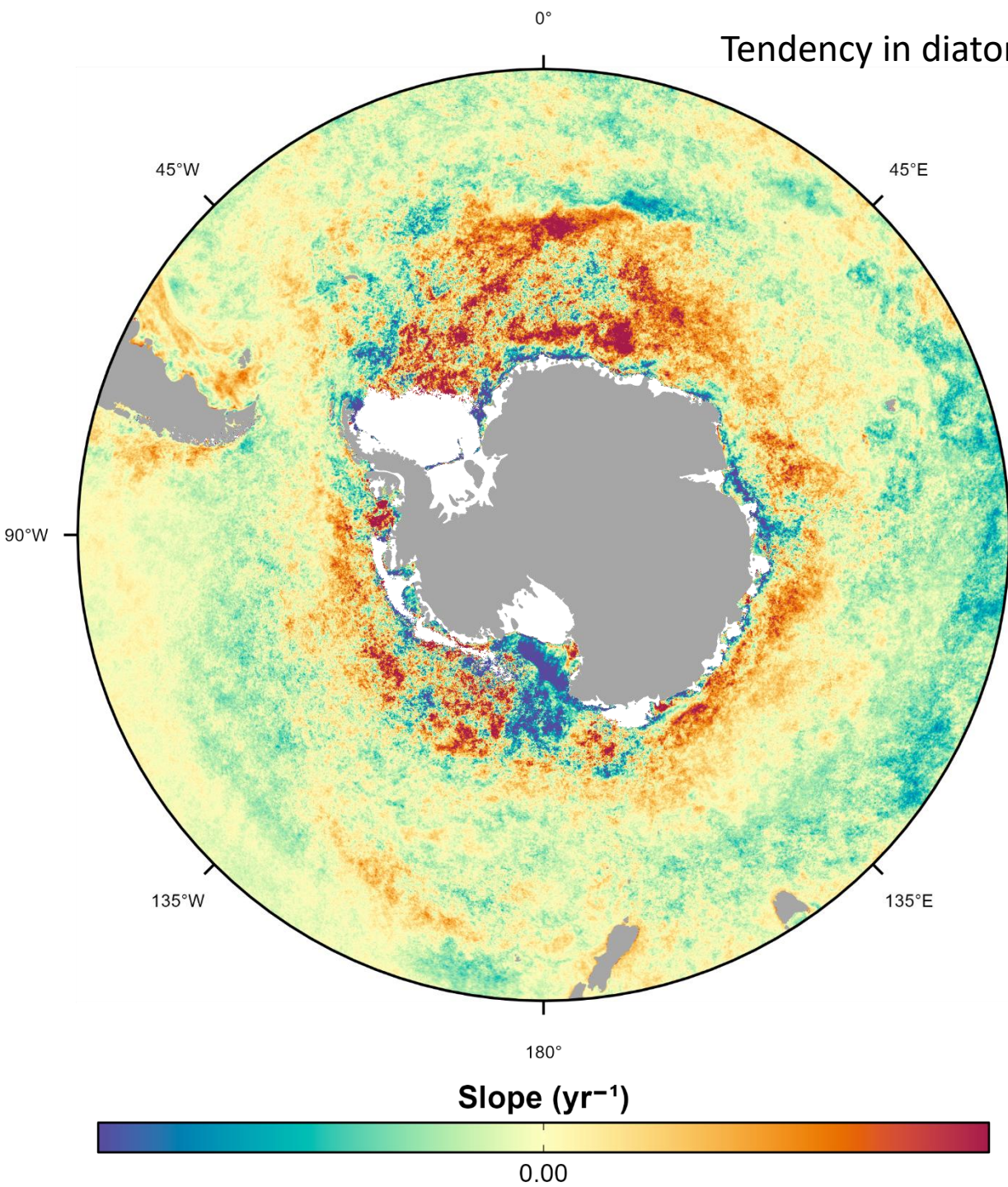
Slope (yr⁻¹)

0.00

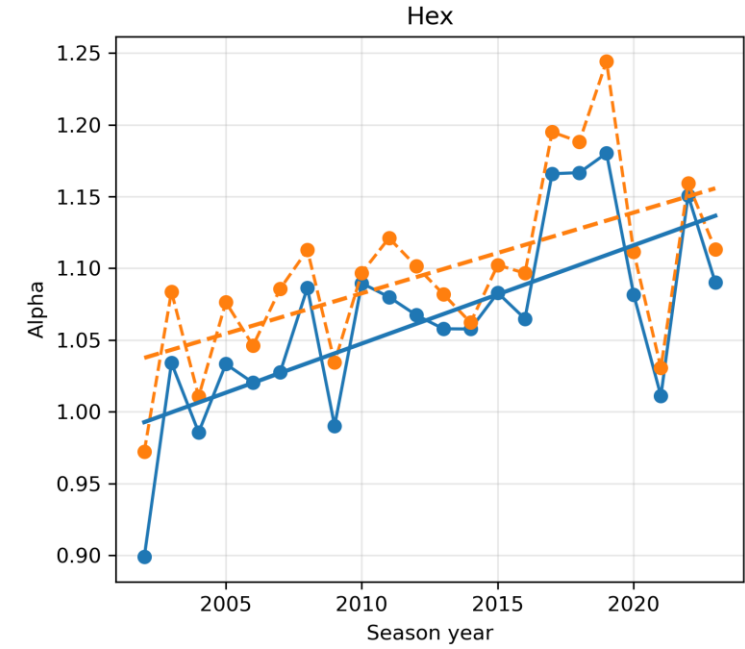
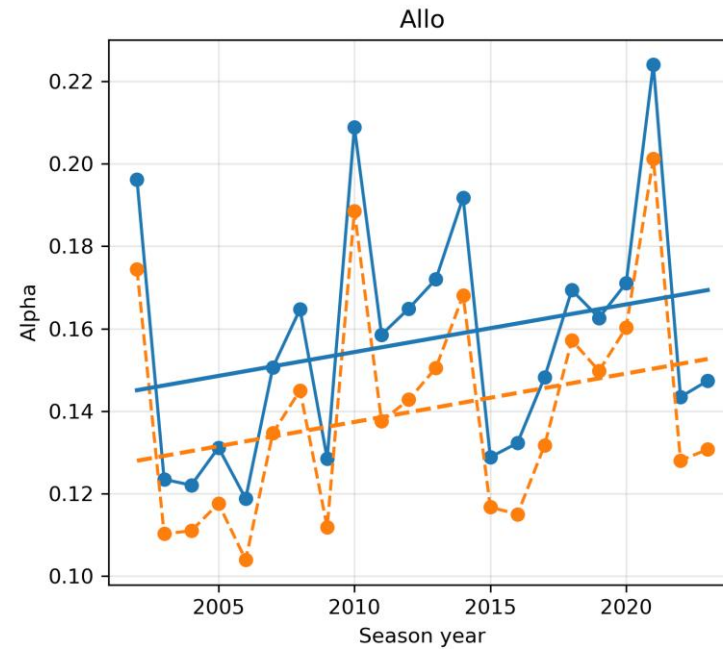
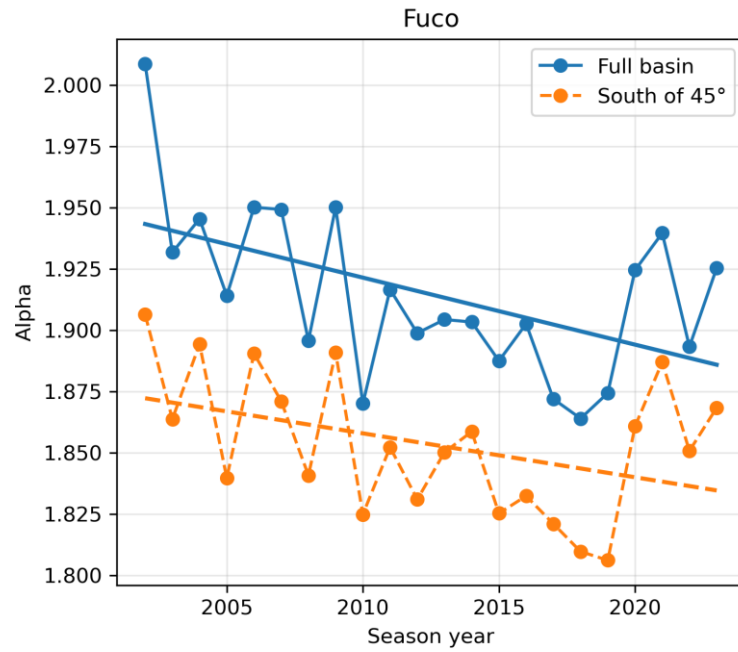
Tendency in fucoxanthin (diatoms) (absolute value)



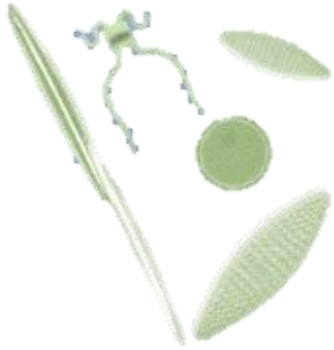
Tendency in diatoms (relative value to Chla)



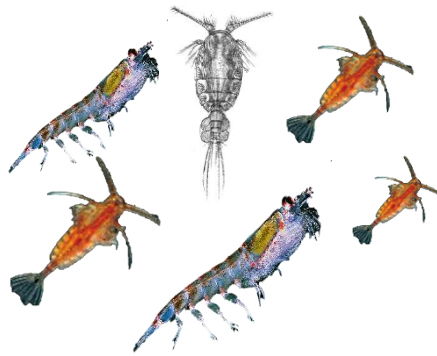
Pigment tendency (relative value to Chla)



Phytoplankton



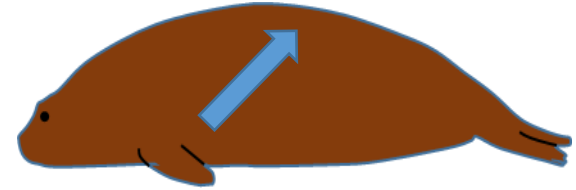
Zooplankton



Micronekton



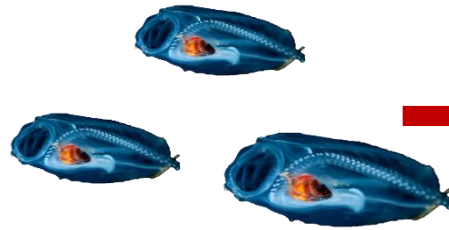
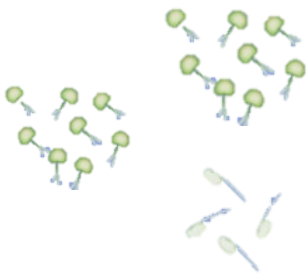
Top marine predators (sentinels)



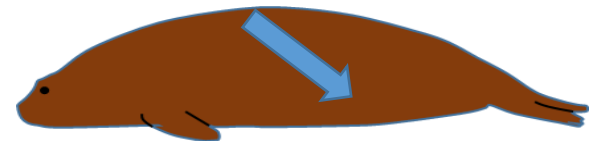
Foraging performances

Diatoms
(Large size high
nutritional
value)

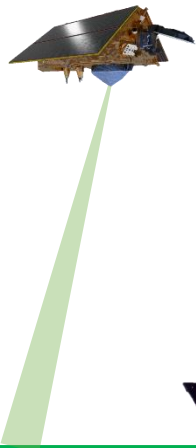
Pico-nano-
phytoplankton
(small size,
low
nutritionnal
value)



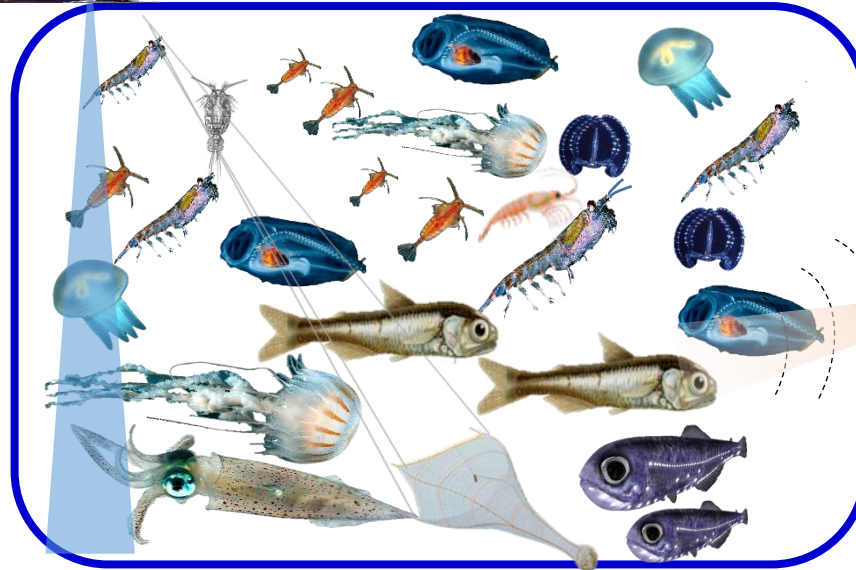
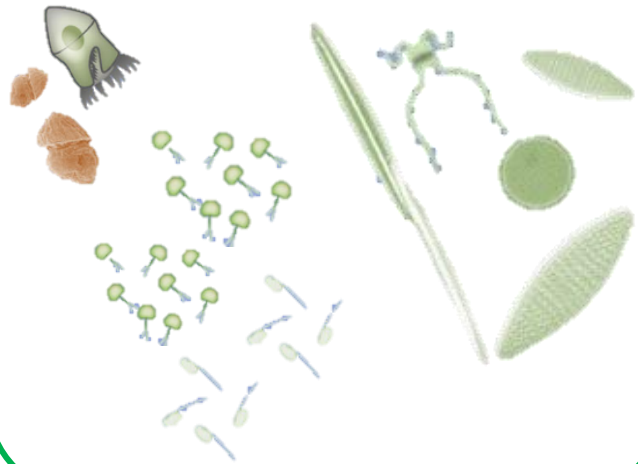
?



New biologgers to investigate the foraging ecology of marine predators and the biology of the Ocean.

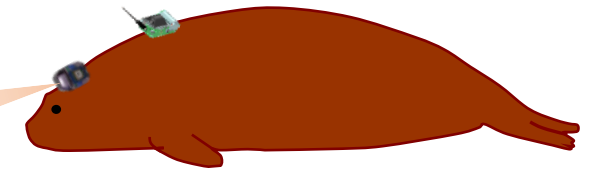


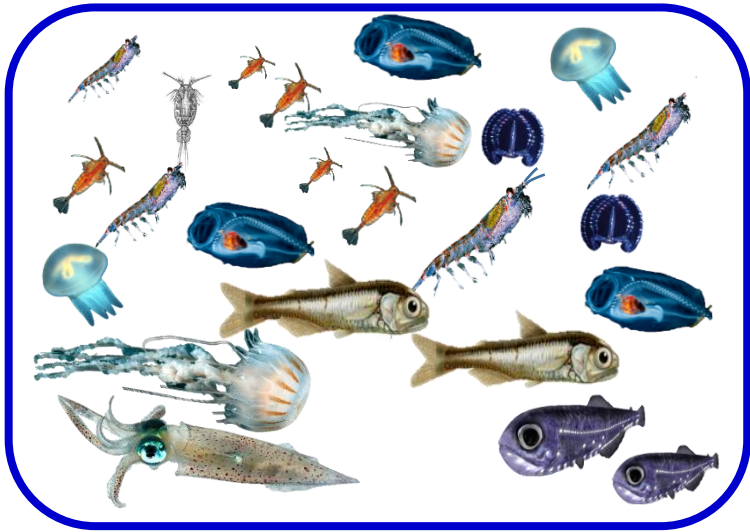
Phytoplankton



Poorly known Mid-Trophic Levels organisms

Investigate the foraging ecology of marine predators



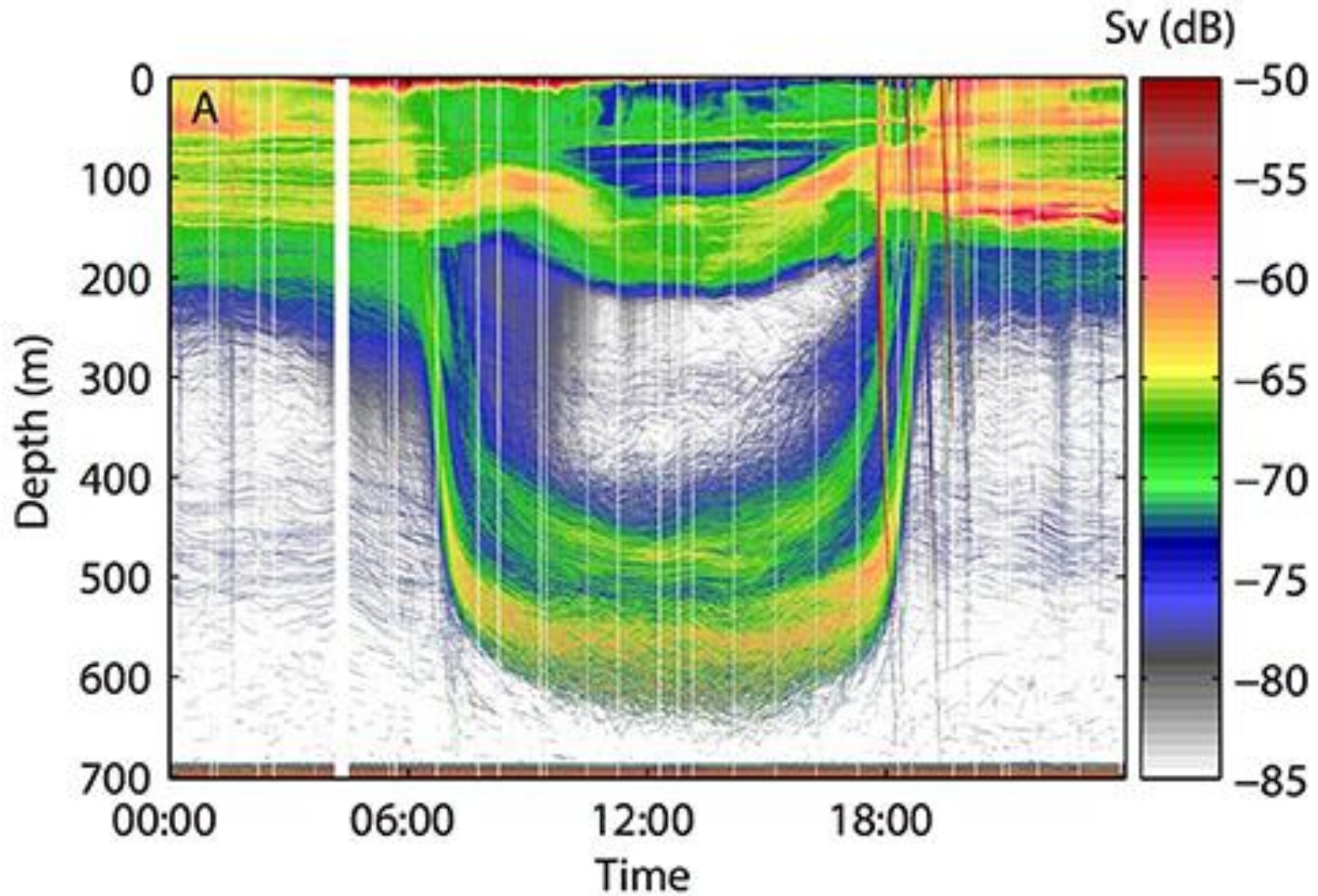


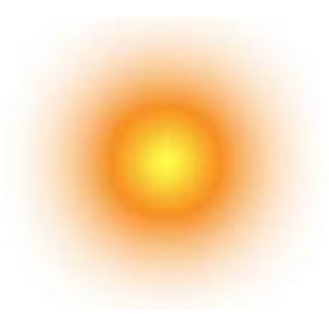
Mid Trophic Levels organisms

Largest animal biomass on Earth
(10 to 16 billions tons)

Largest daily biomass migration on Earth

A major contribution to the biological
carbon (CO₂) export to depth





Épipélagic

0

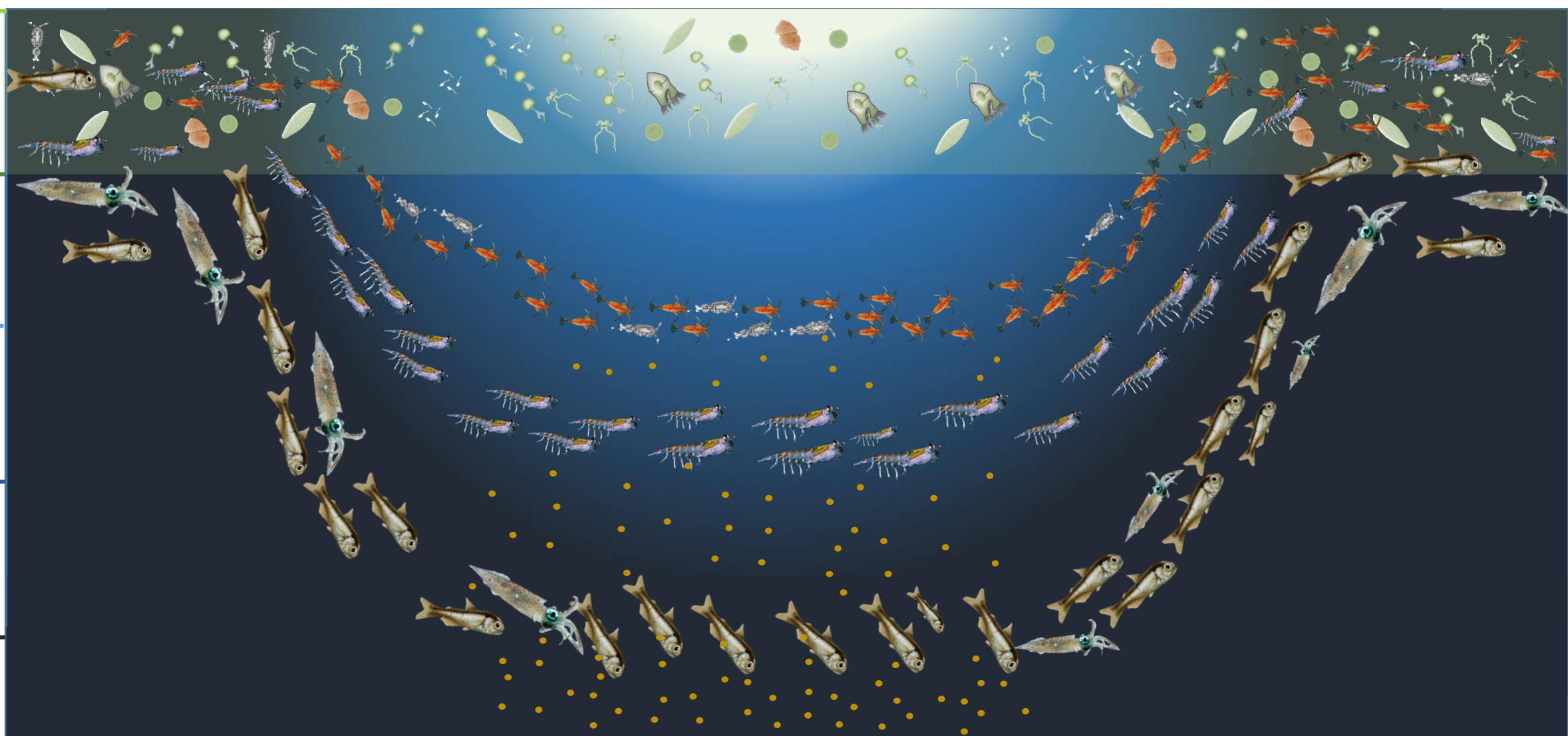
200

Mésopélagic

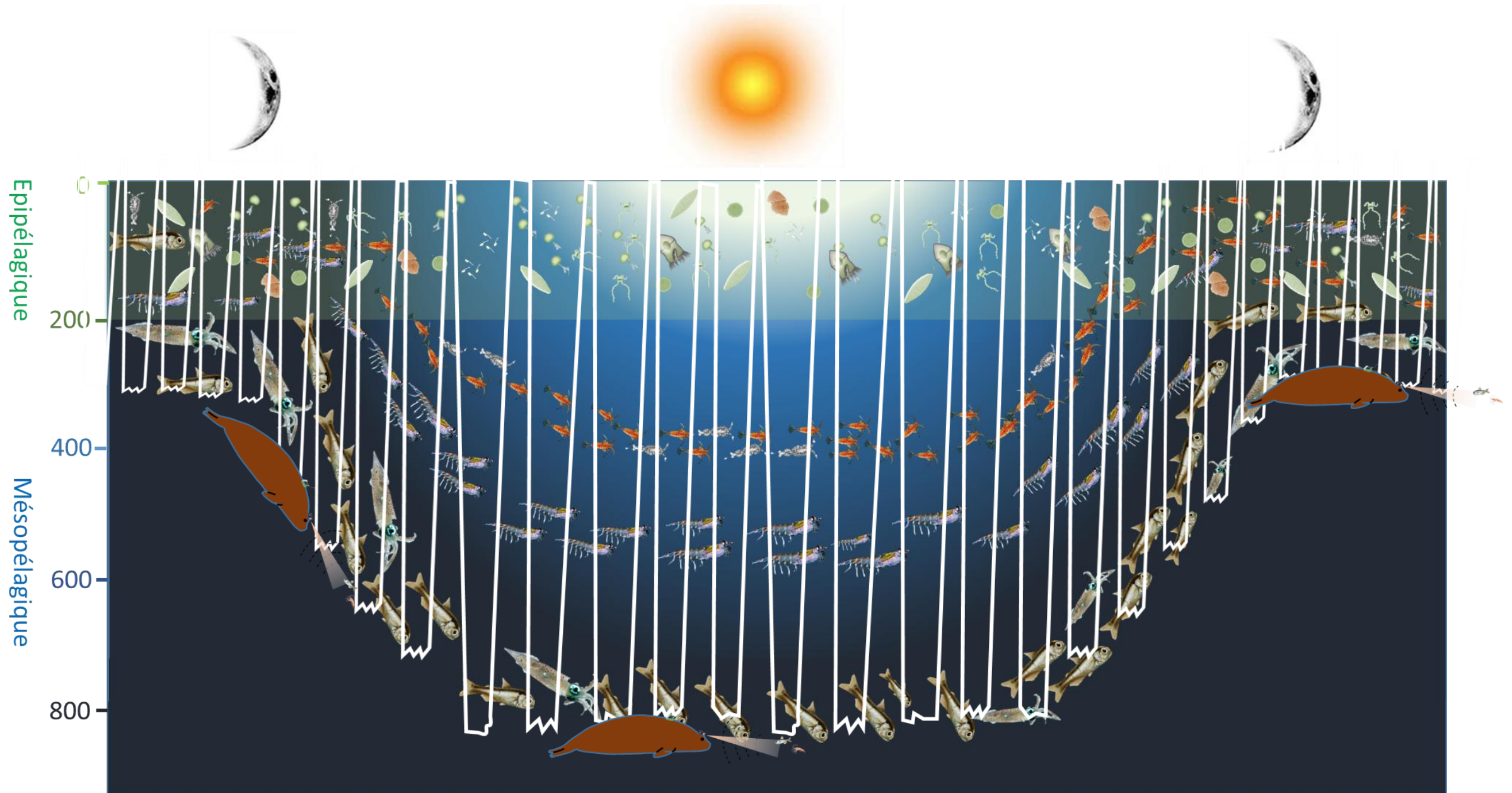
400

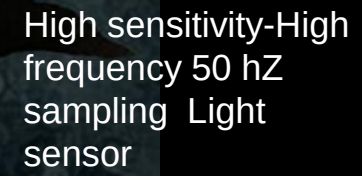
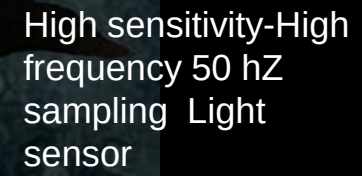
600

800

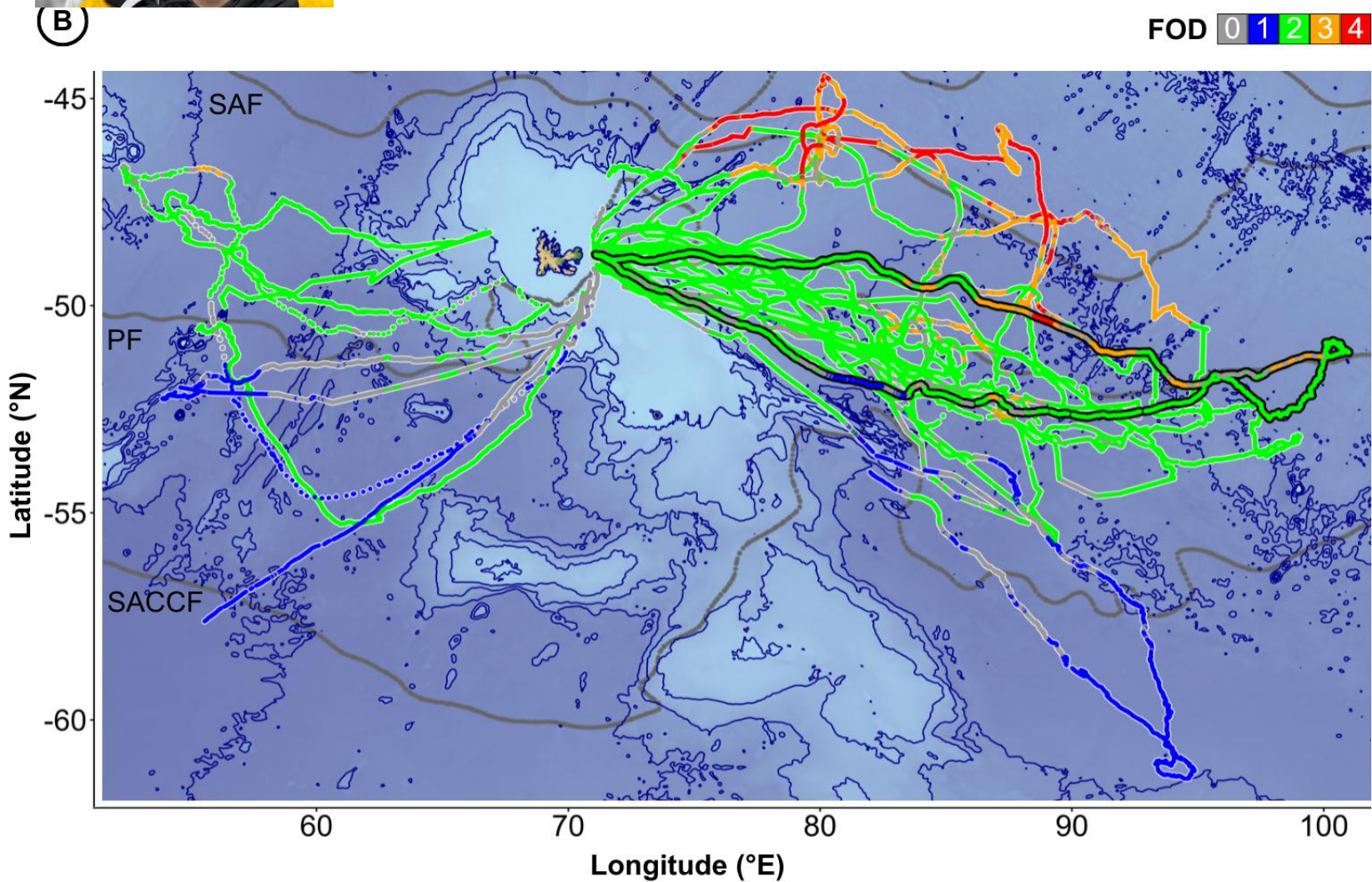
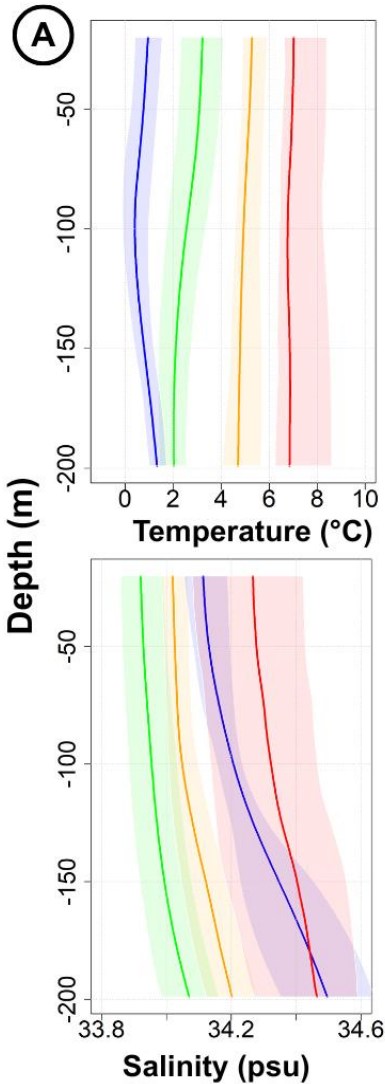


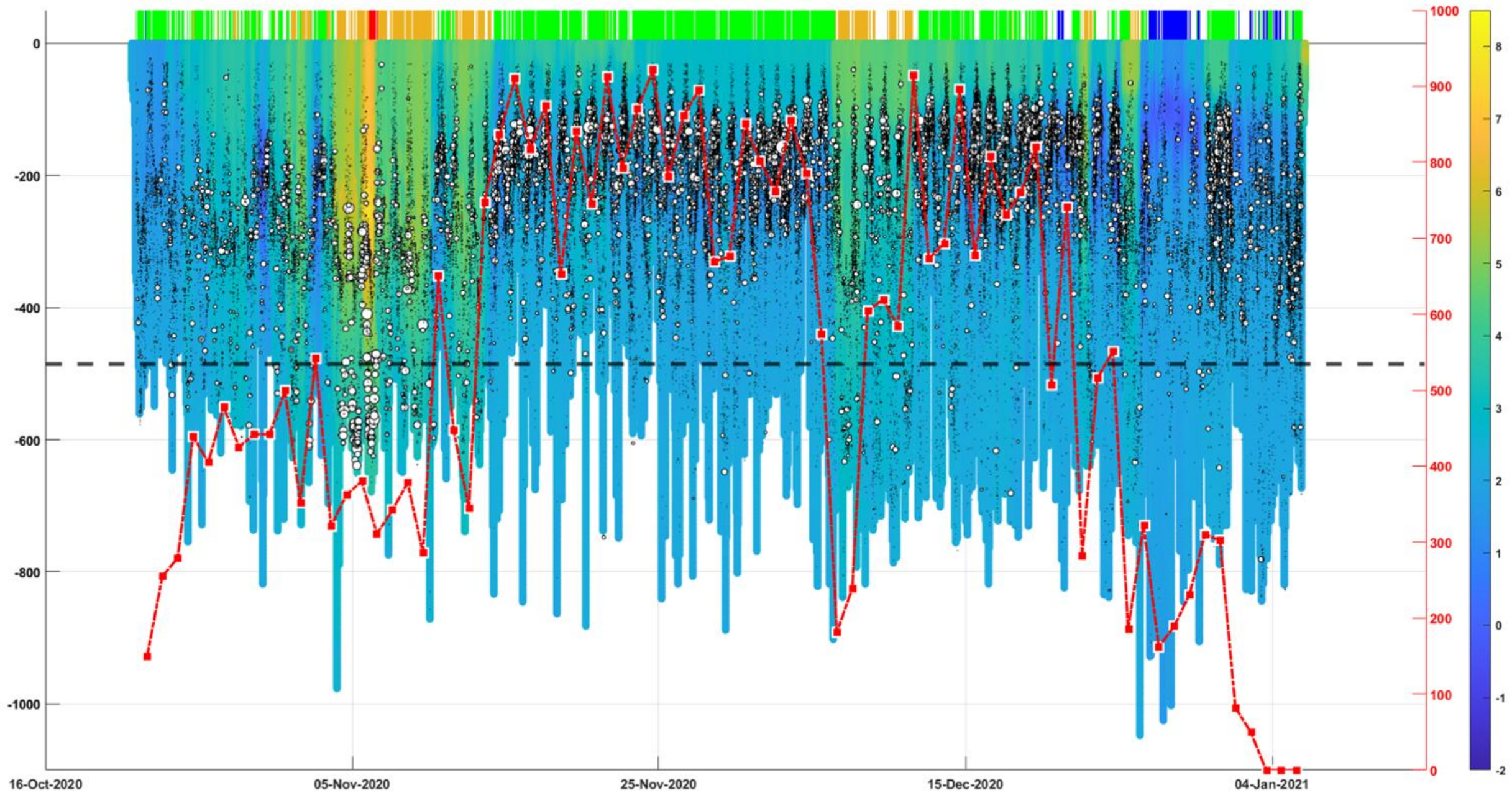
Quelle est la distribution et le comportement des organismes rencontrés par les éléphants de mer ?

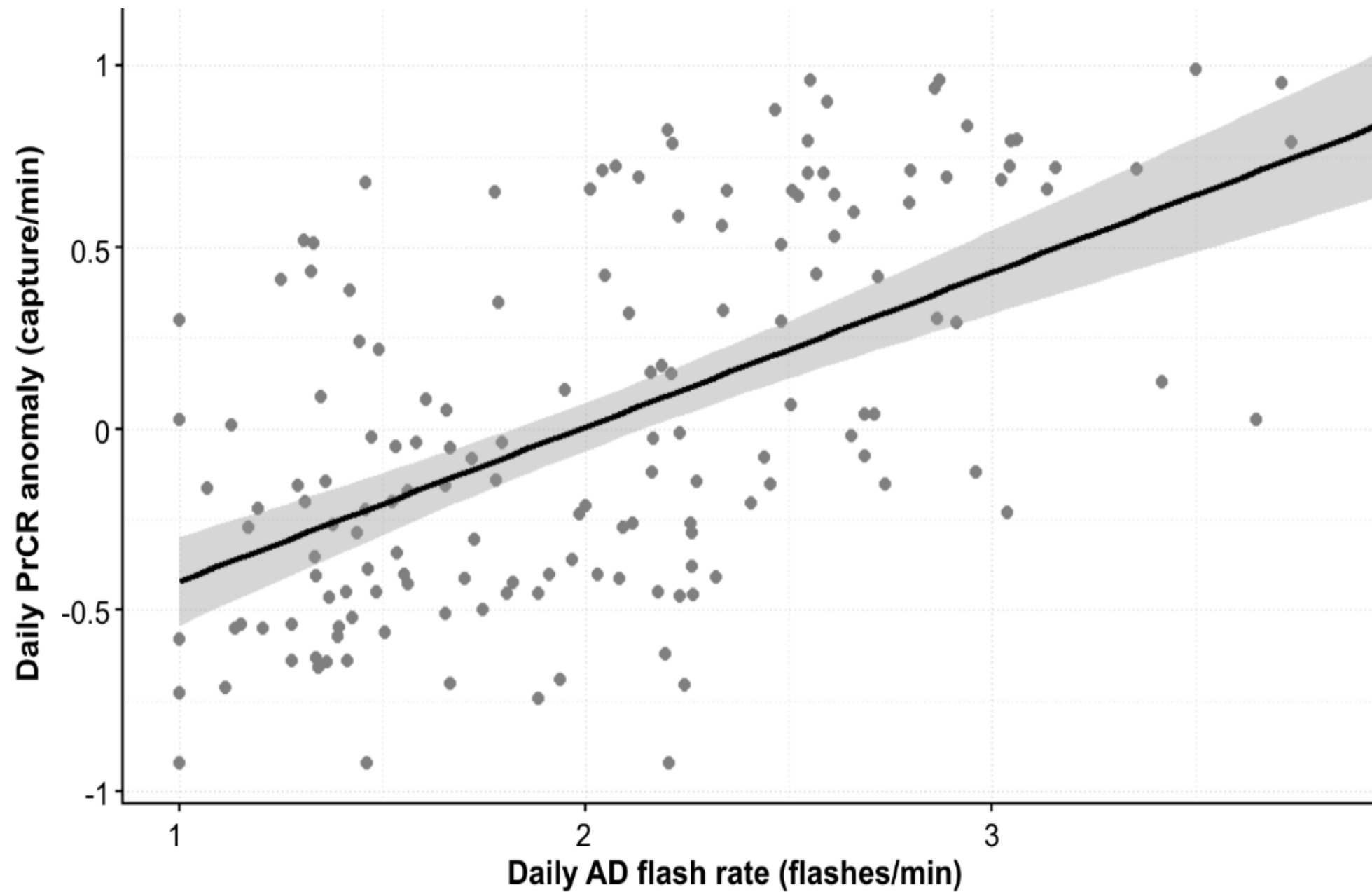


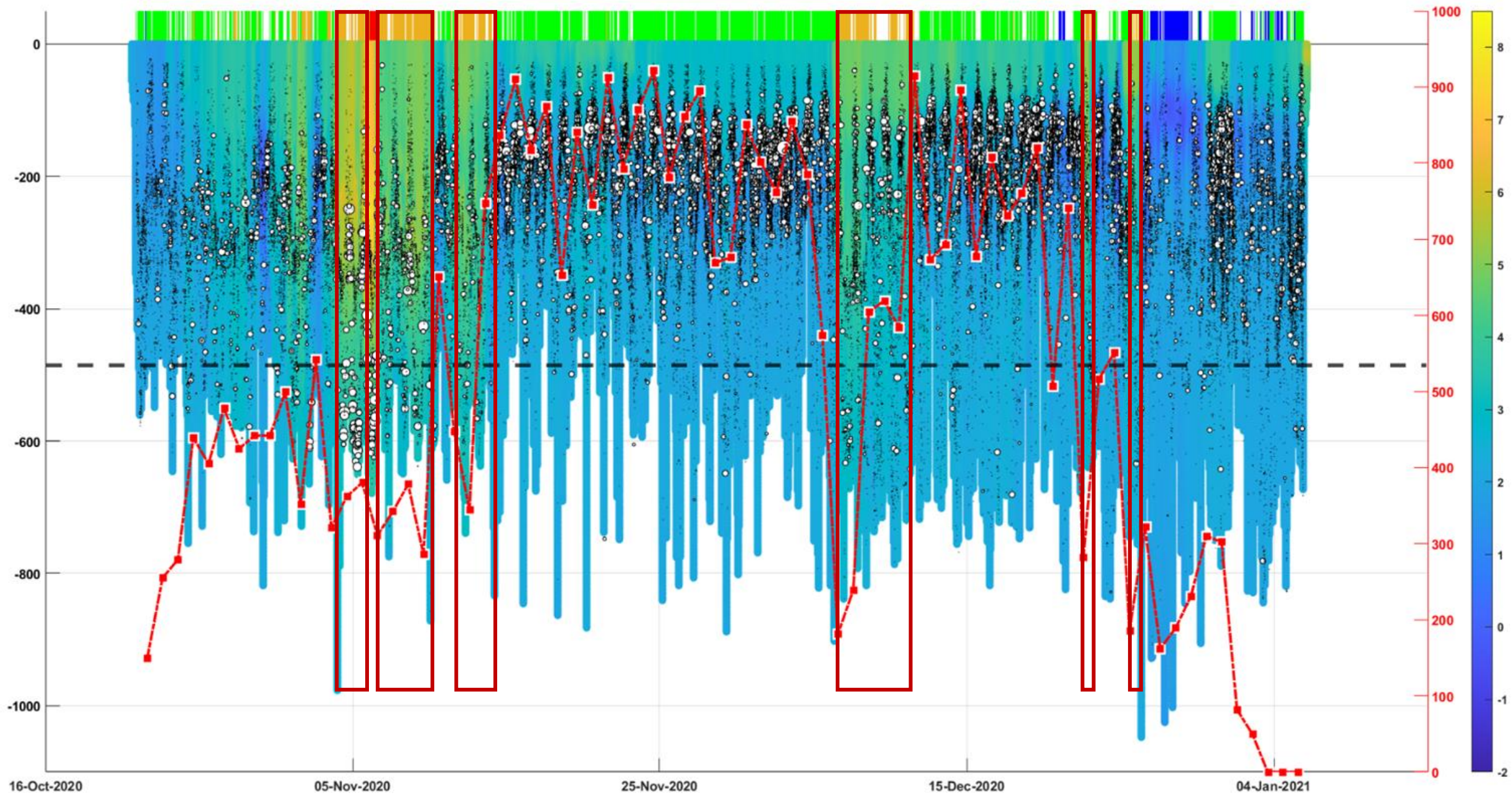


VACQUIÉ-GARCIA J., ROYER F., DRAGON A.C., VIVIAN M., BAILLEUL F., GUINET C. 2012. Foraging in the darkness of the Southern Ocean: influence of Bioluminescence on a deep diving predator. *Plos One*





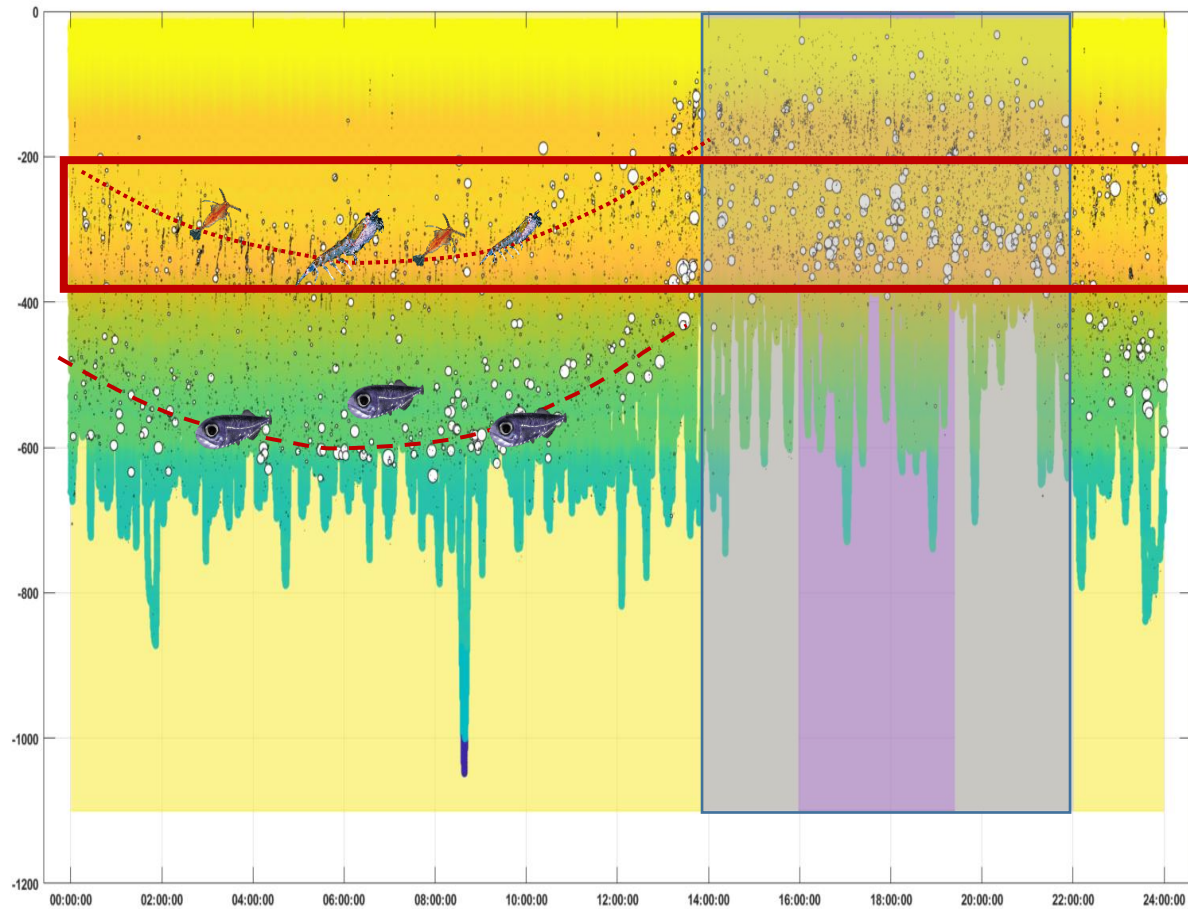




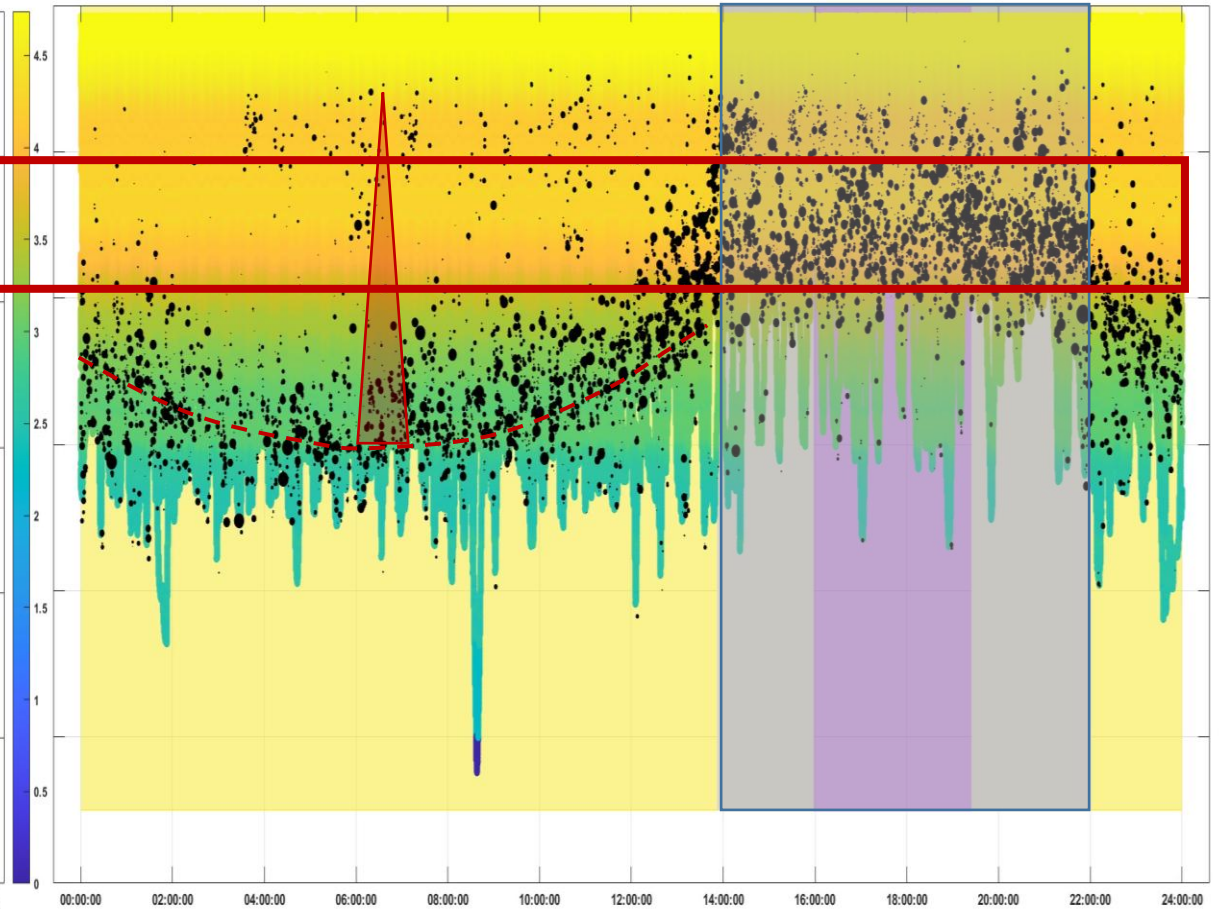
Bioluminescence

Day

Night

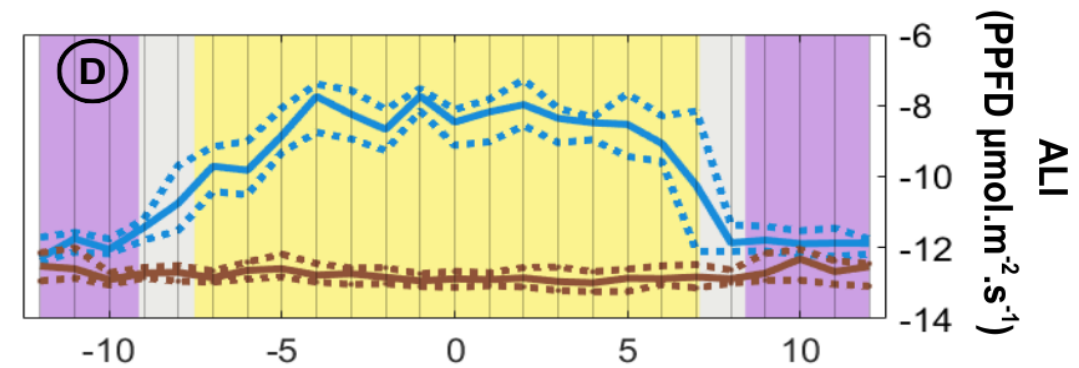
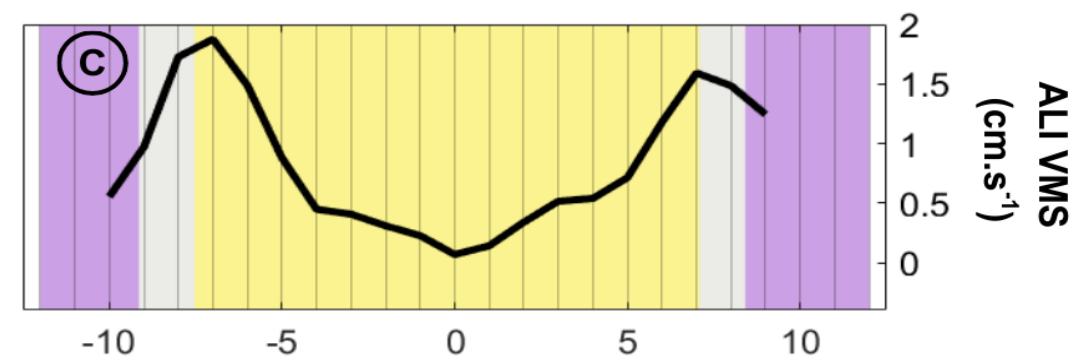
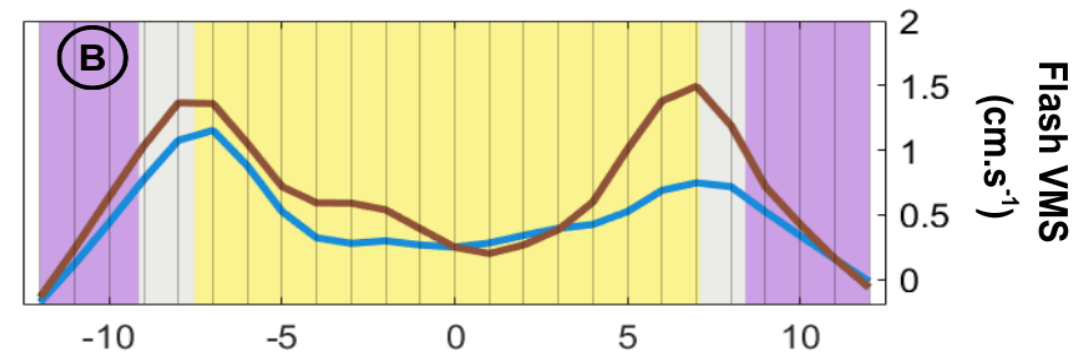
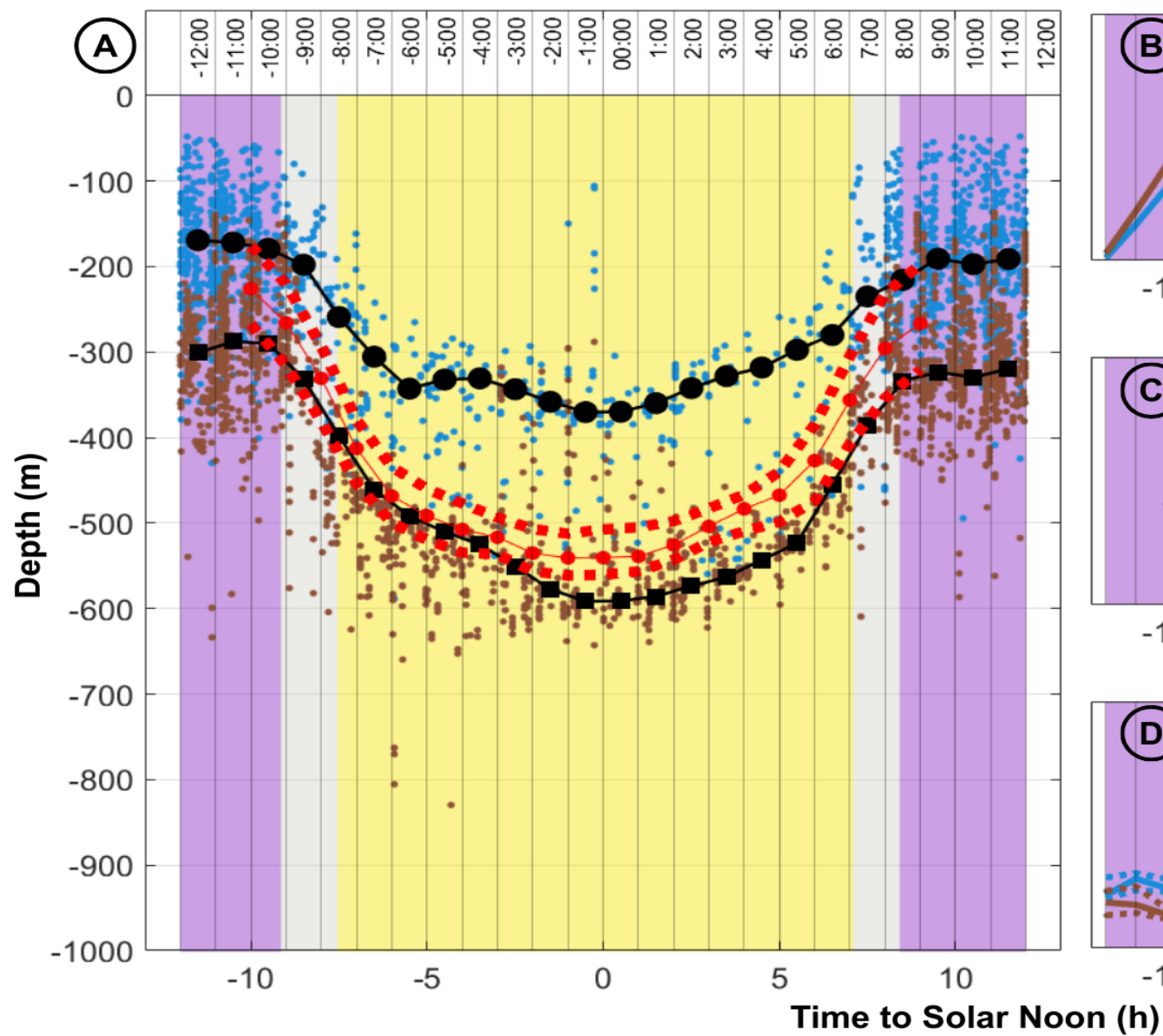


Prey Catch Attempts



FOD 3

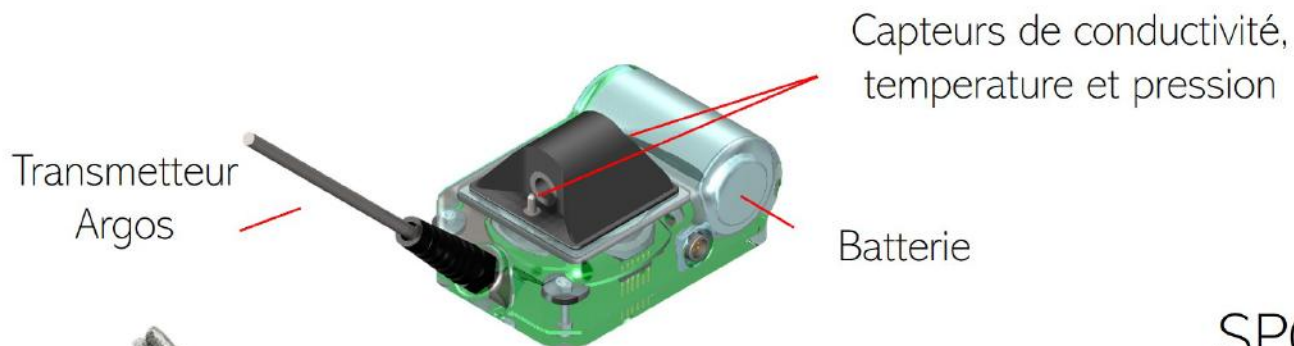
Goulet et al. J. Exp. Biol. (2020); Uzan et al. (MEPS (2026)); Clabaux et al. Science Advances (Soumis)



CTD-SRD

105 x 70 x 40 mm

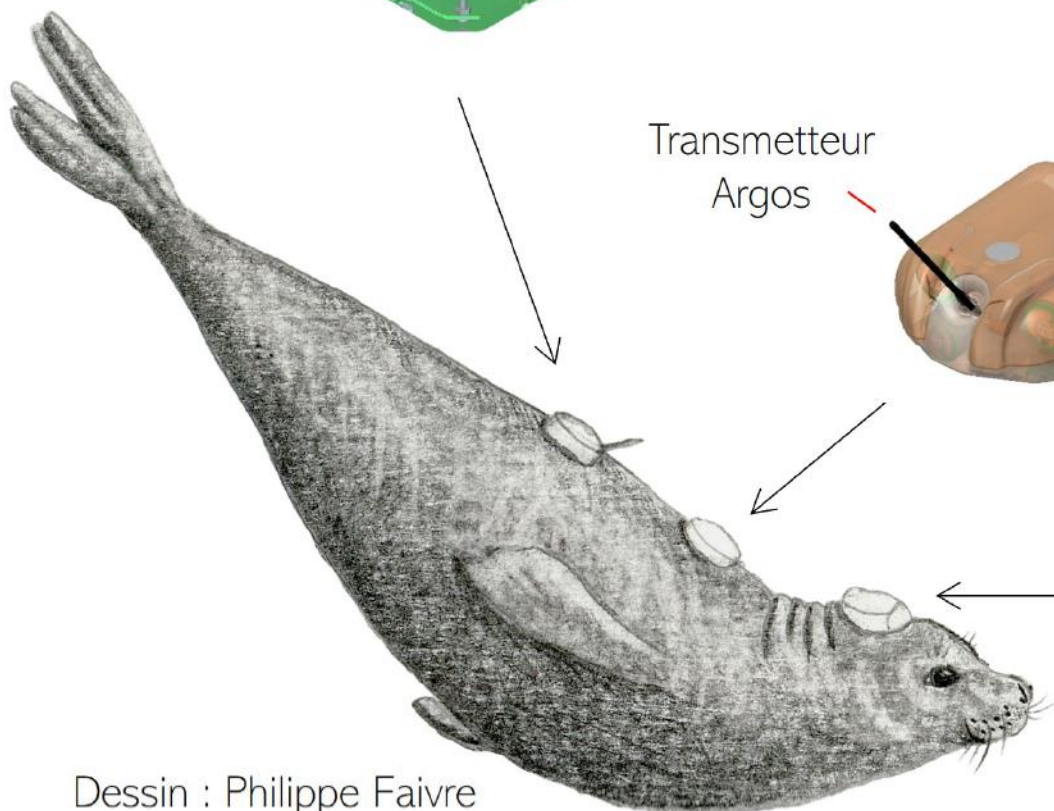
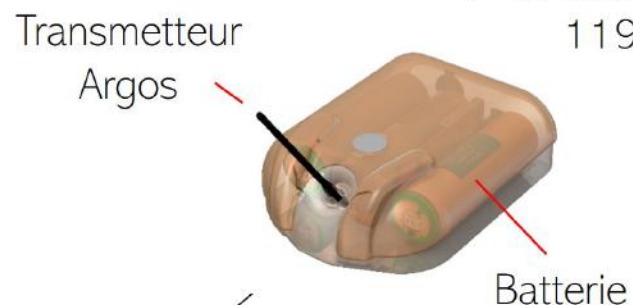
545 g



SPOT-293

72 x 56 x 24 mm

119 g

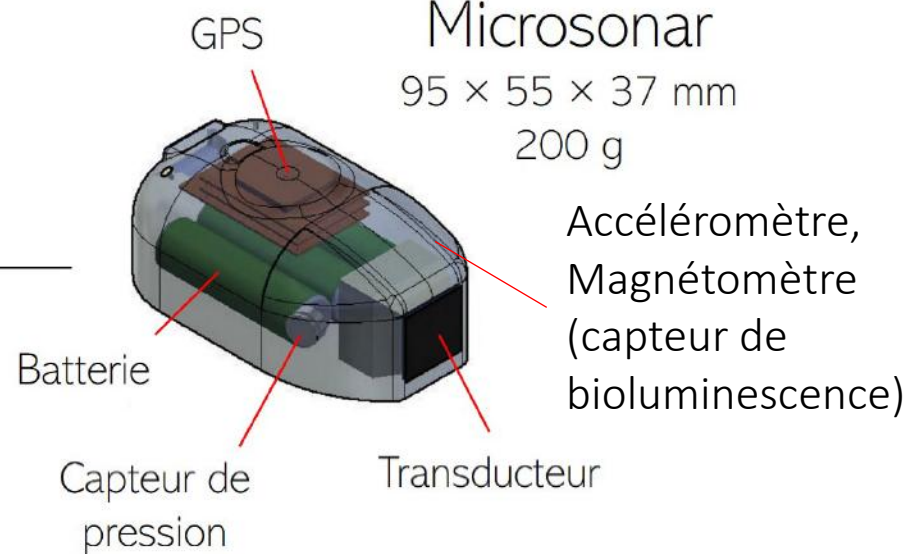


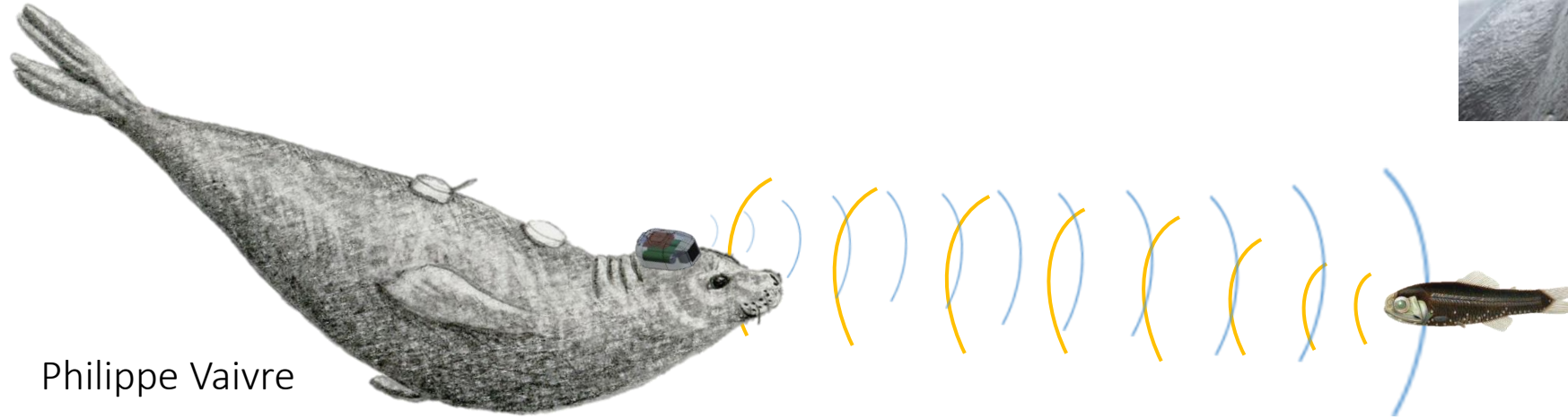
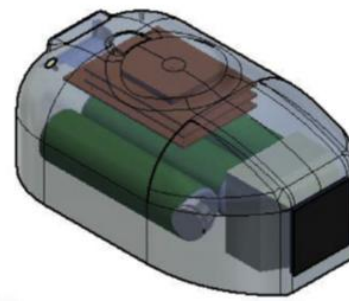
Dessin : Philippe Faivre

Microsonar

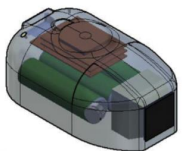
95 x 55 x 37 mm

200 g

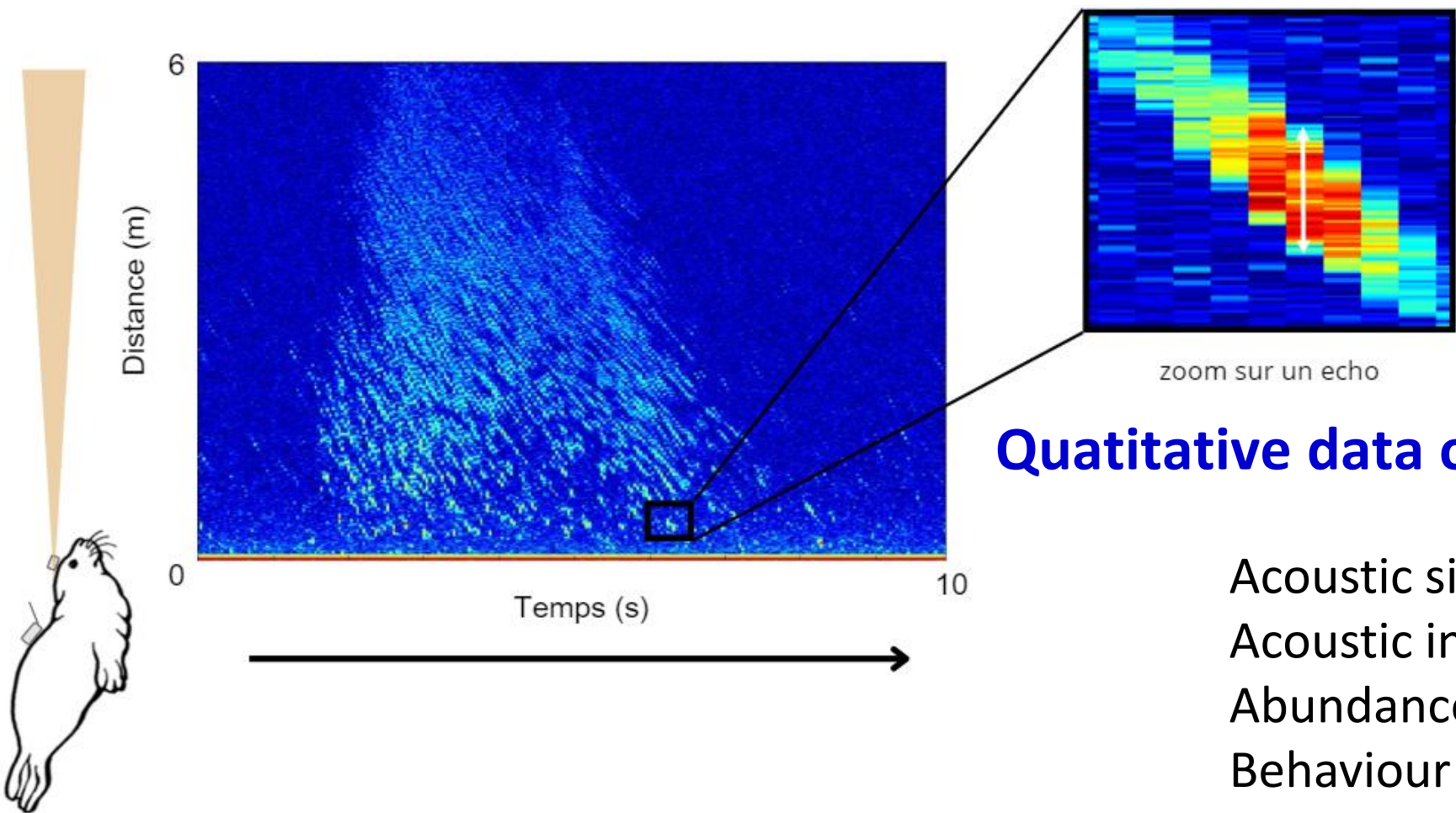
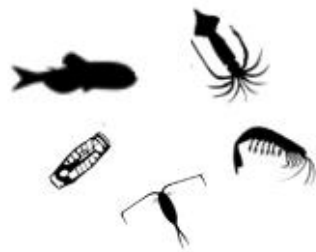
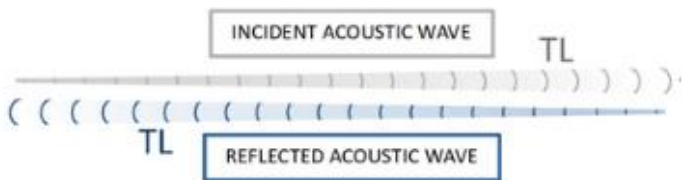




Philippe Vaivre



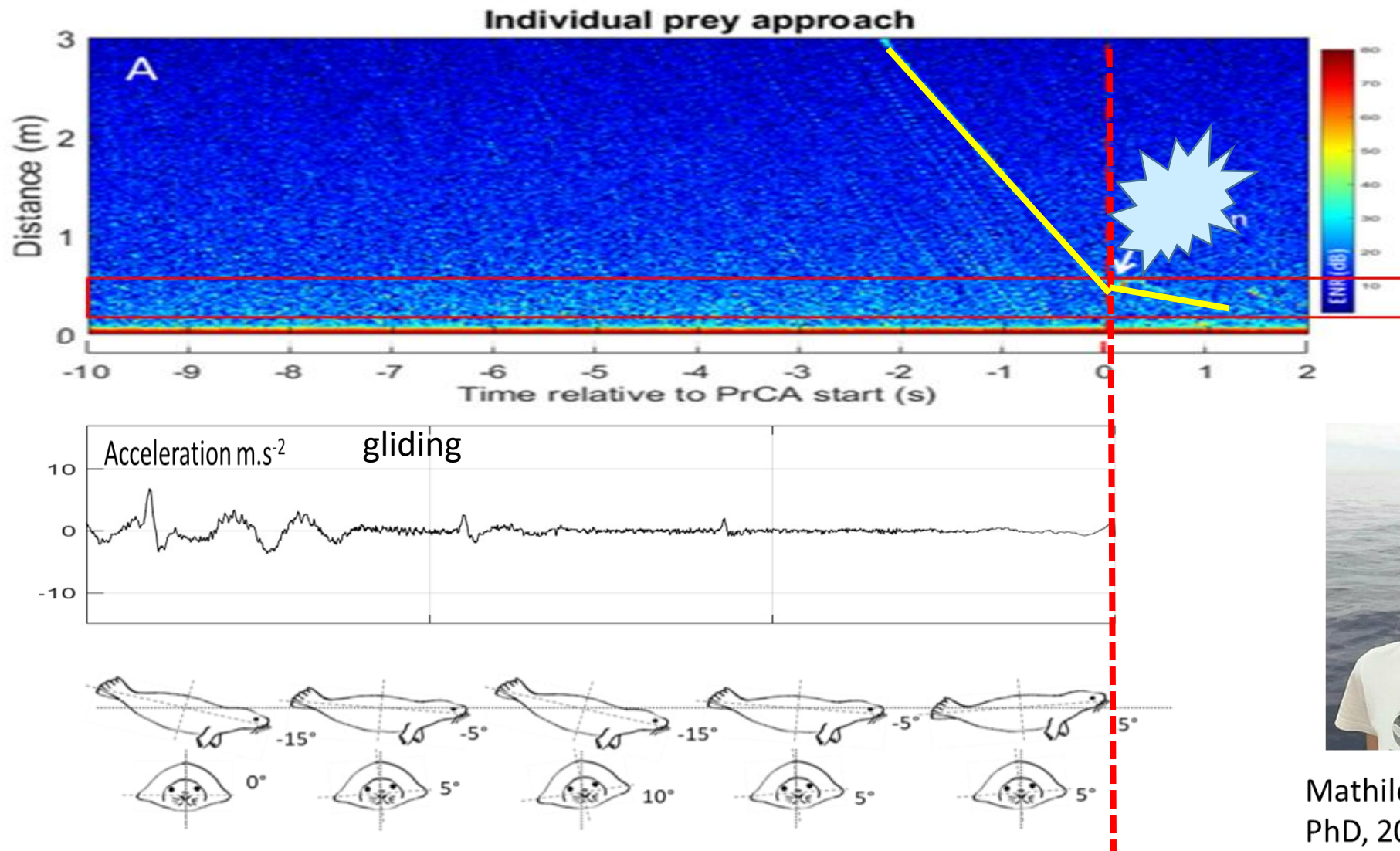
Balise micro-sonar



Quatitative data on echoes

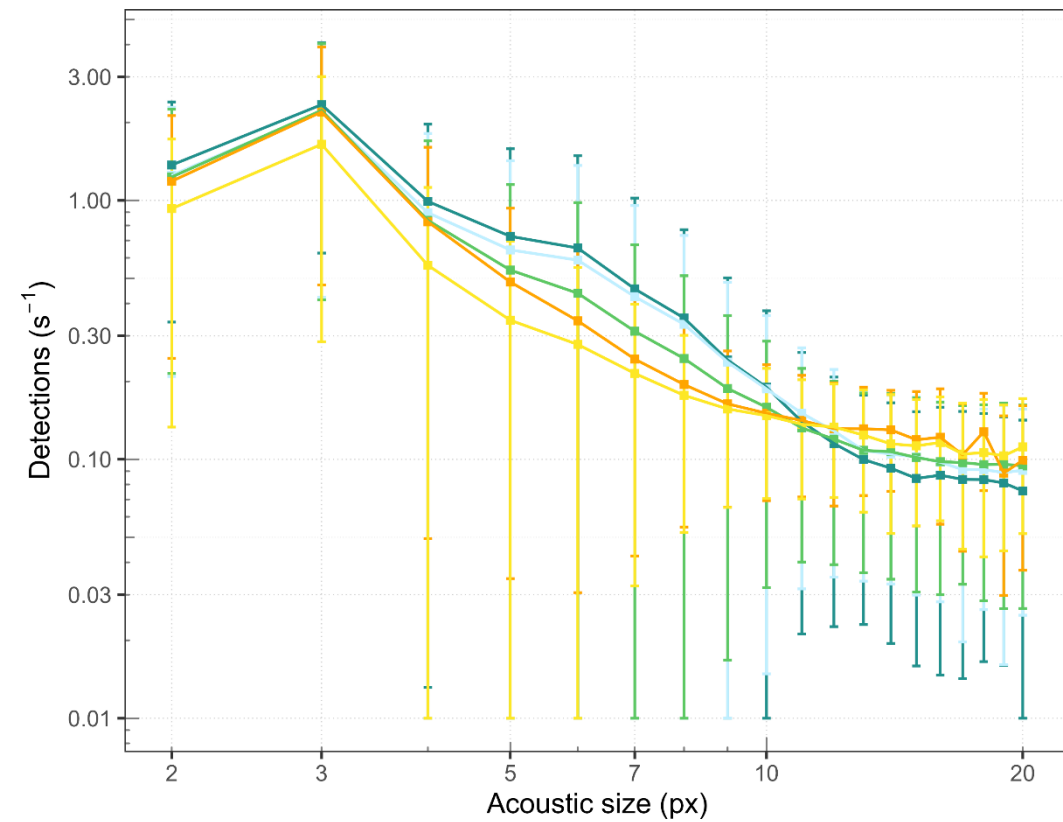
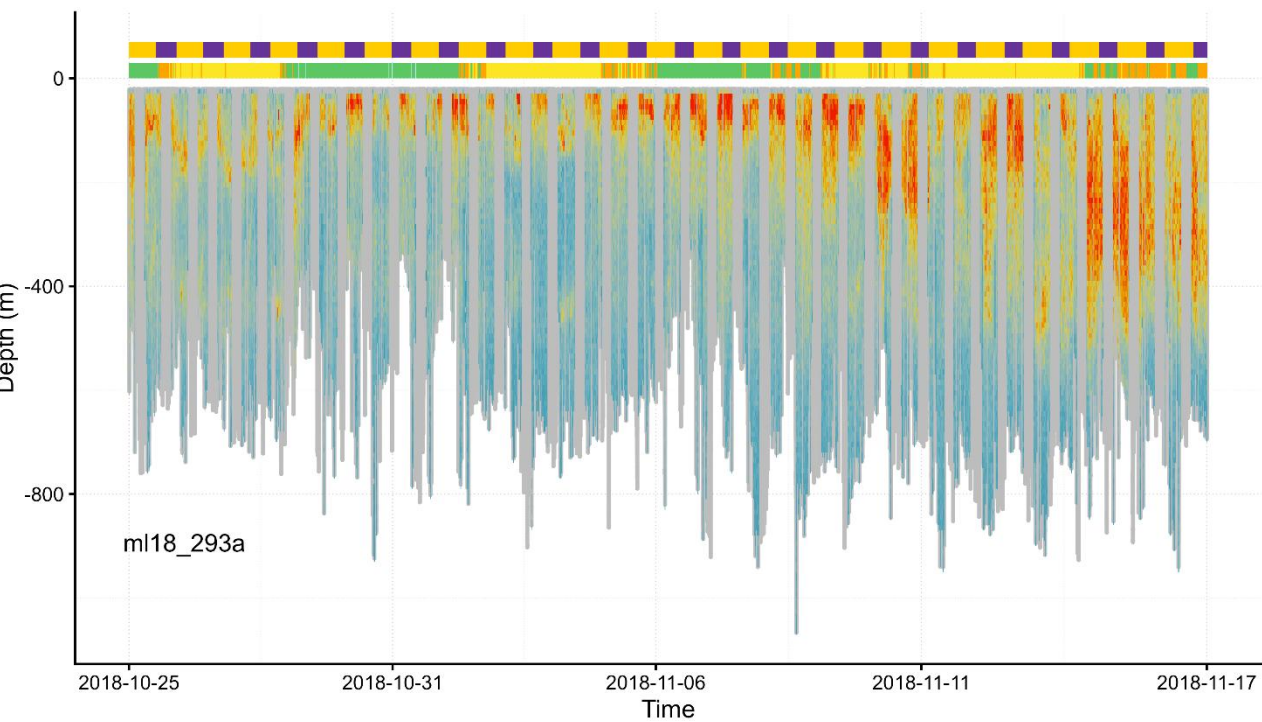
- Acoustic size (>2 mm- 10s of cm)
- Acoustic intensity
- Abundance
- Behaviour

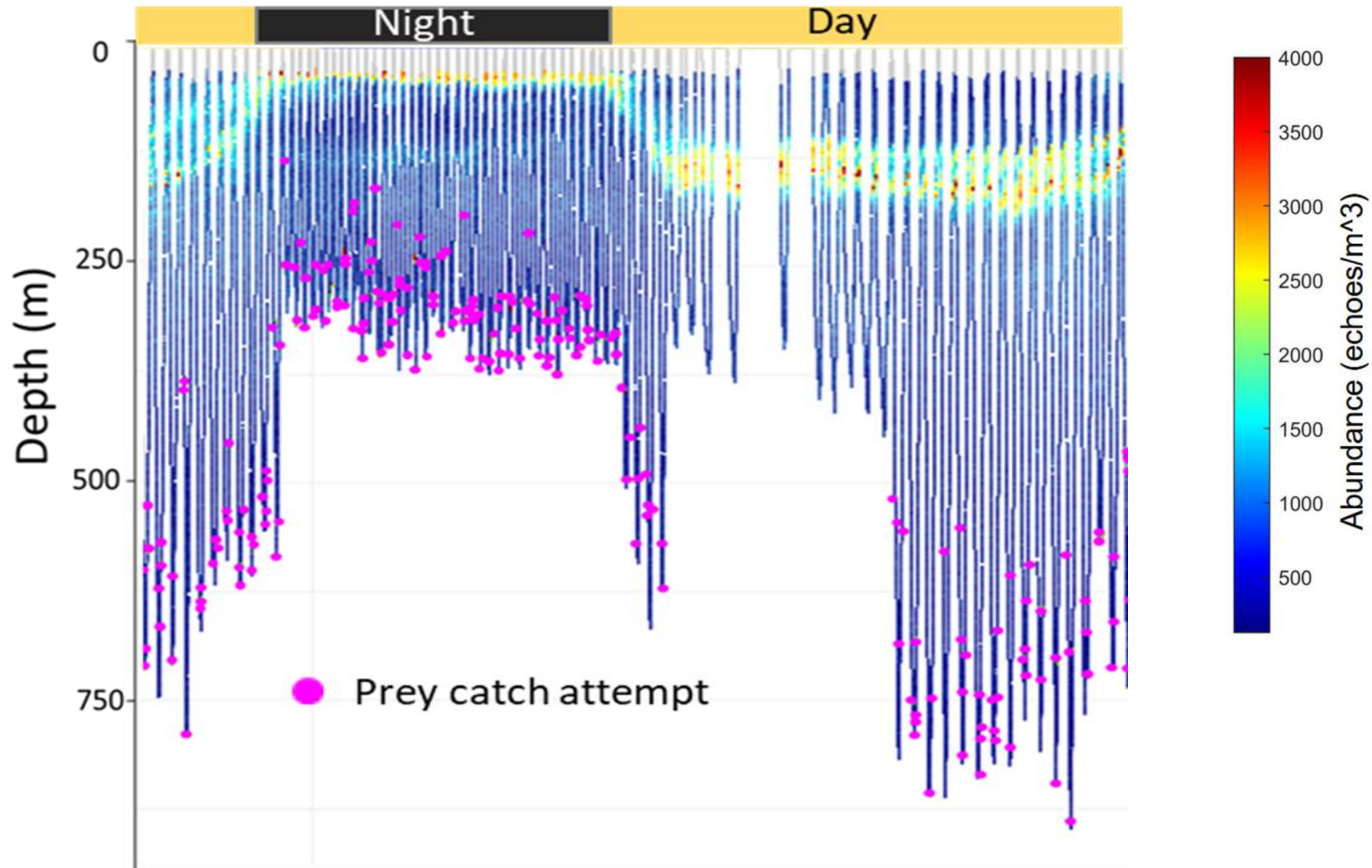
Investigating the foraging behaviour



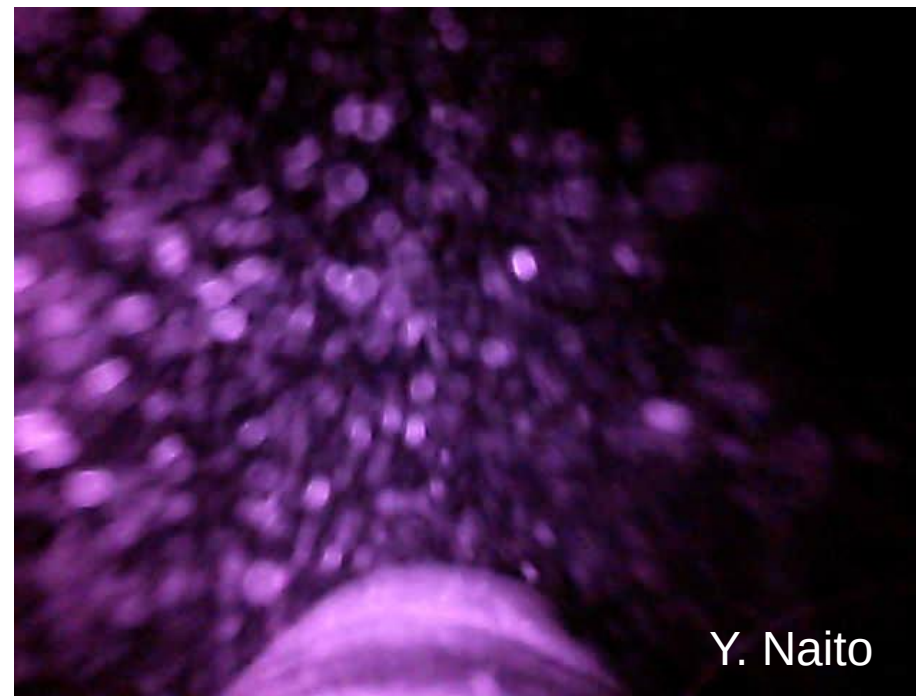
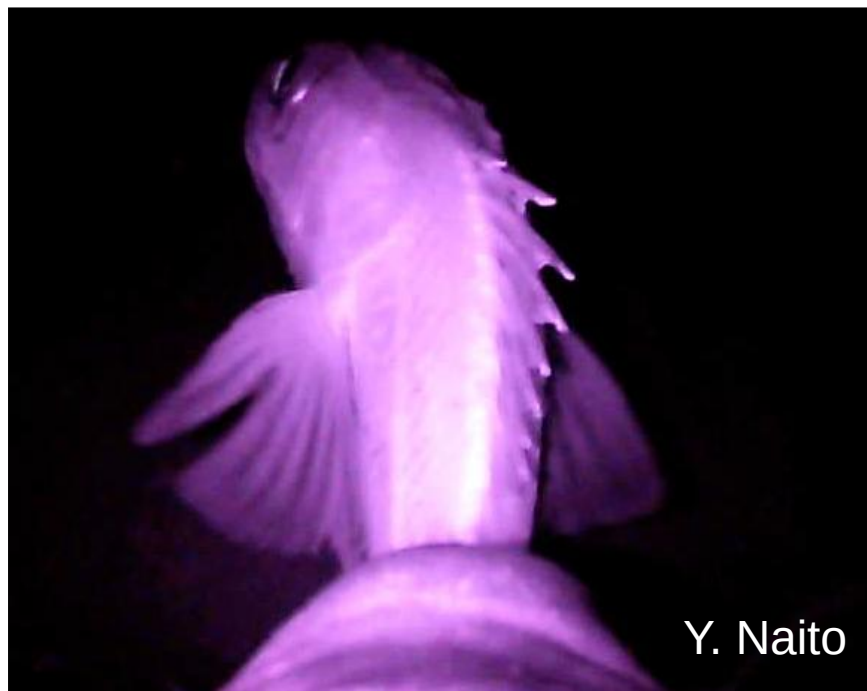
Mathilde Chevallay,
PhD, 2021, CEBC

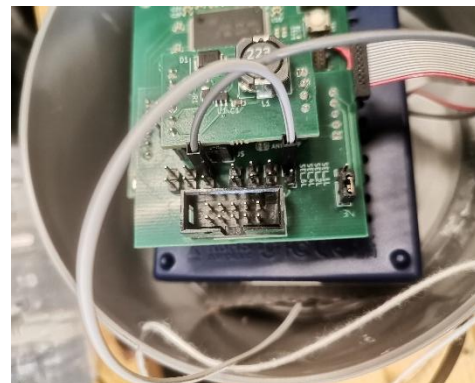
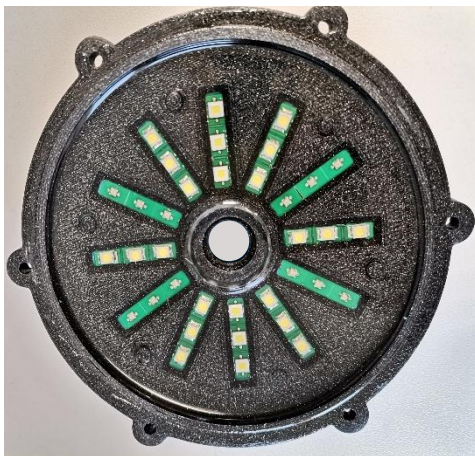
Chevallay et al. (2023)





Tournier M, Goulet P, Johnson M, Nerini D, Fonvieille N, Guinet C (2021). A novel animal-borne miniature echosounder to observe the distribution and migration patterns of intermediate trophic levels in the Southern Ocean. *Journal of Marine System*, 223: 103608. <https://doi.org/10.1016/j.jmarsys.2021.103608>



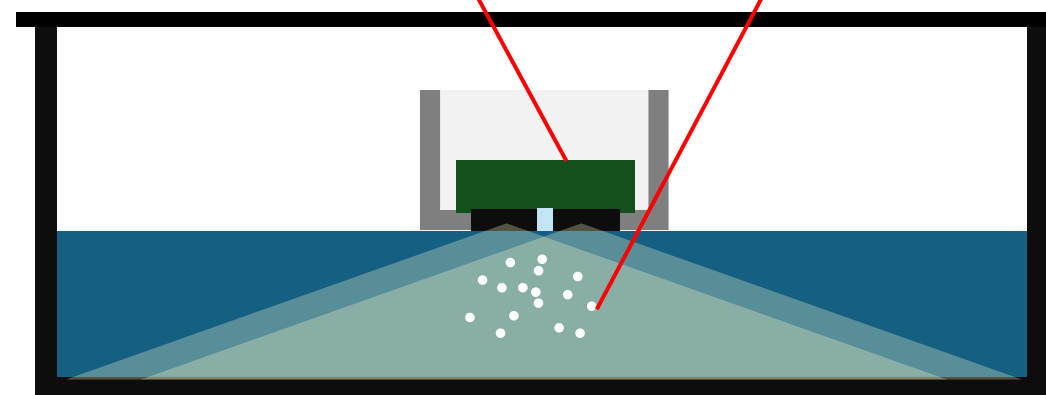


Guilhem
Carriou



Daphnies
vivantes

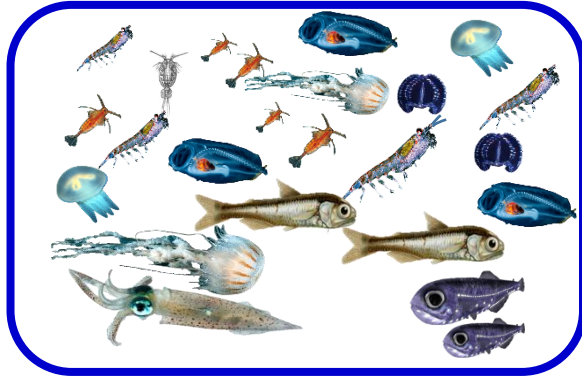
1mm to 3mm



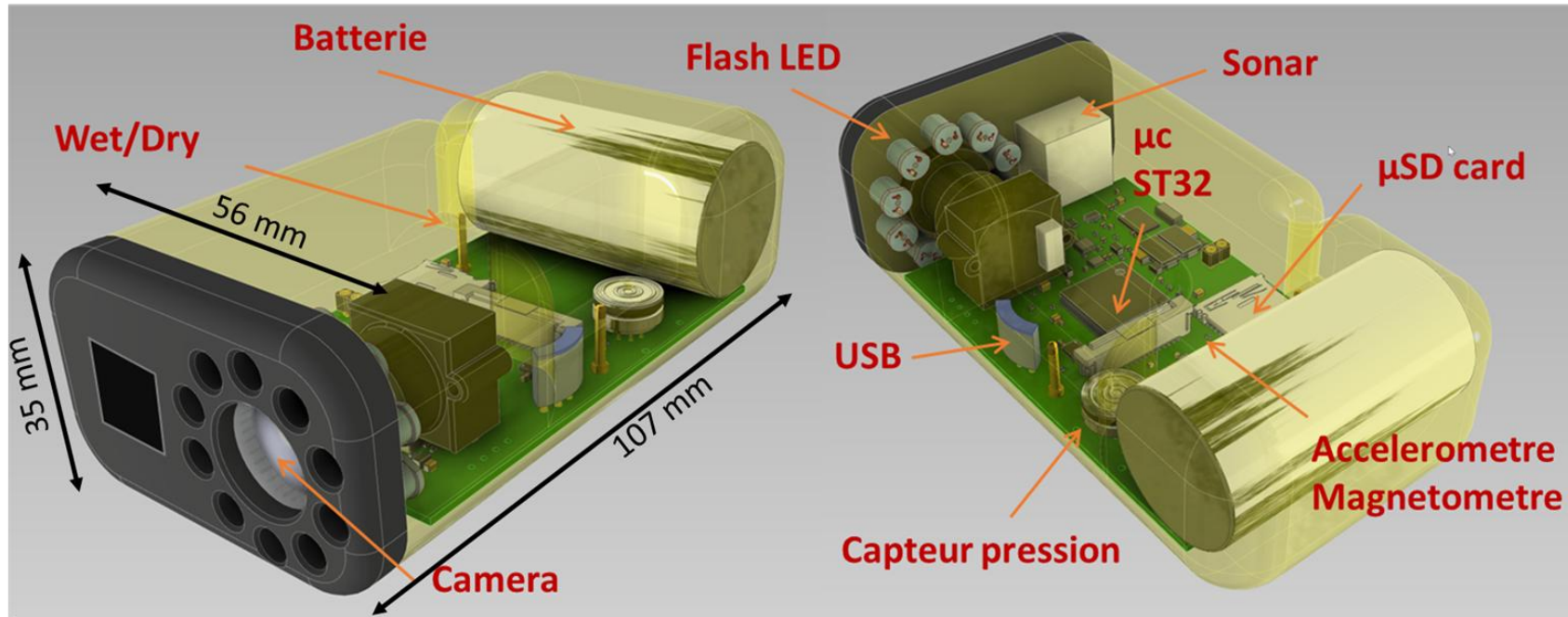
Bâche noire opaque

Bassin noir

L'A2V- μ Cam : Combining a micro-sonar and a camera



Better characterise the Mid Trophic levels



Conclusion:

- Develop new biologgers to better evaluate the biological component of the Ocean.
- Assess the influence of the vertical structure of oceanographic conditions on the distribution of marine organisms
- Understand the variation in MTL abundance and composition in relation to the composition of phytoplankton communities.
- While studying the at-sea ecology of elephant seals



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"Eléphants de mer
nouvelles
sentinelles"



Questions?