20 ans d'observations de l'Océan Austral par les éléphants de mer tout en étudiant leur écologie.

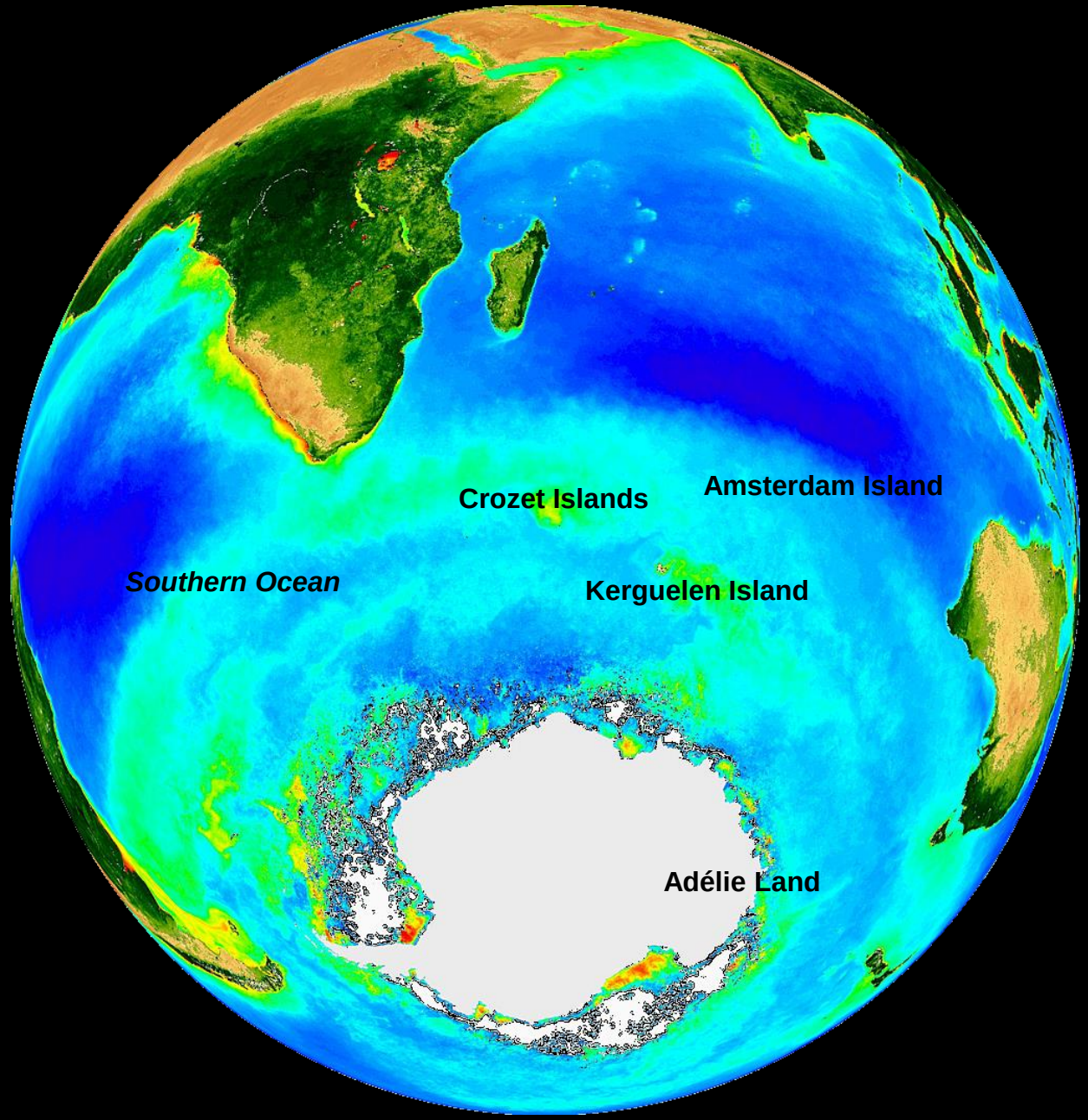
Christophe Guinet[1],
Baptiste Picard[1], Pauline Goulet[1], Didier Goulet-Tran[1], Marius Clabaux[1], Marius Molinet[1], Peio Uhart[1], Mathilde Chevallay[1], Yakov Uzan[1], Tiphaine Jeanniard du Dot[1], Dominique Filippi[2], Mark Johnson[3]

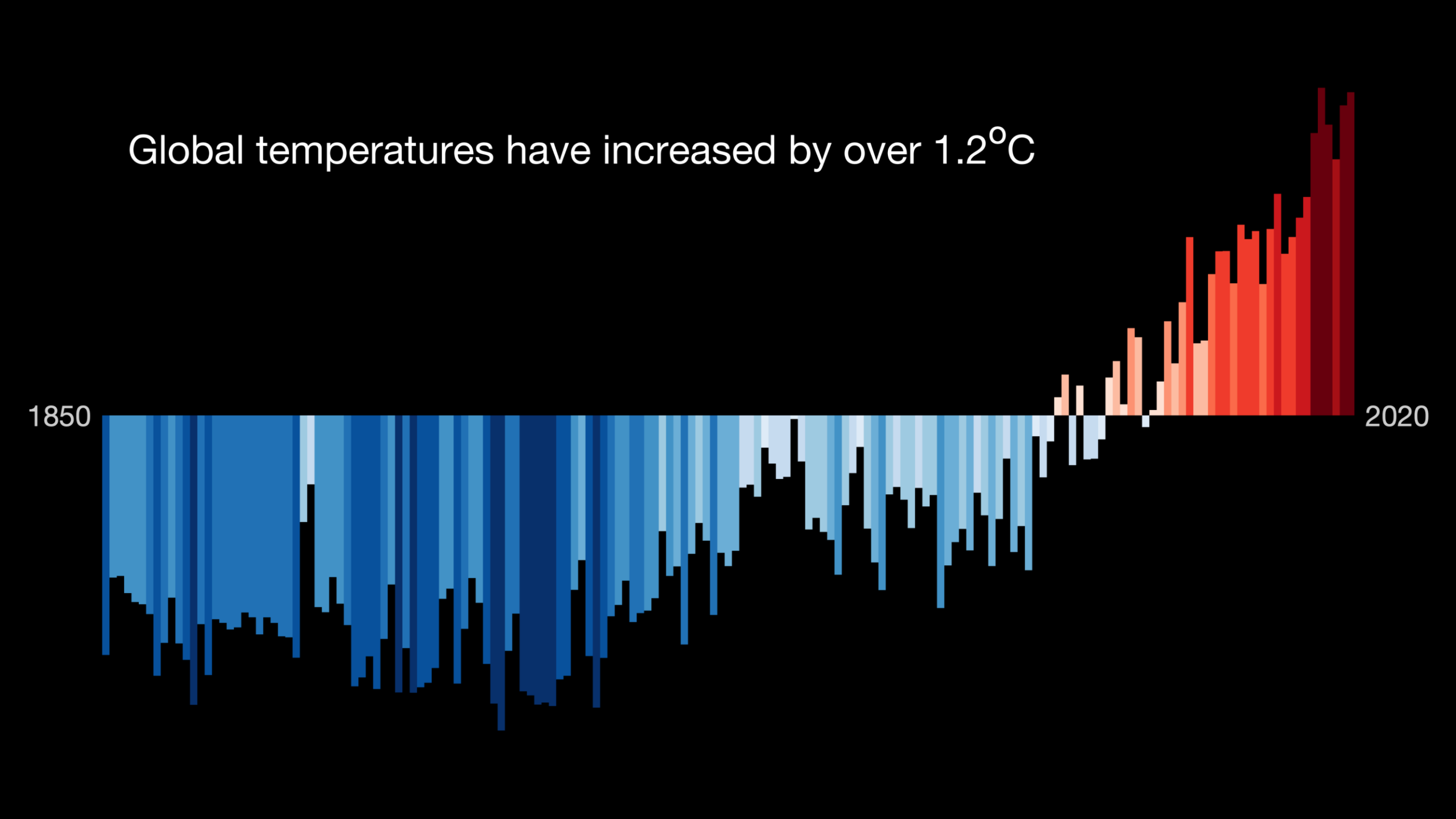
UIA, Niort le 10 octobre 2024

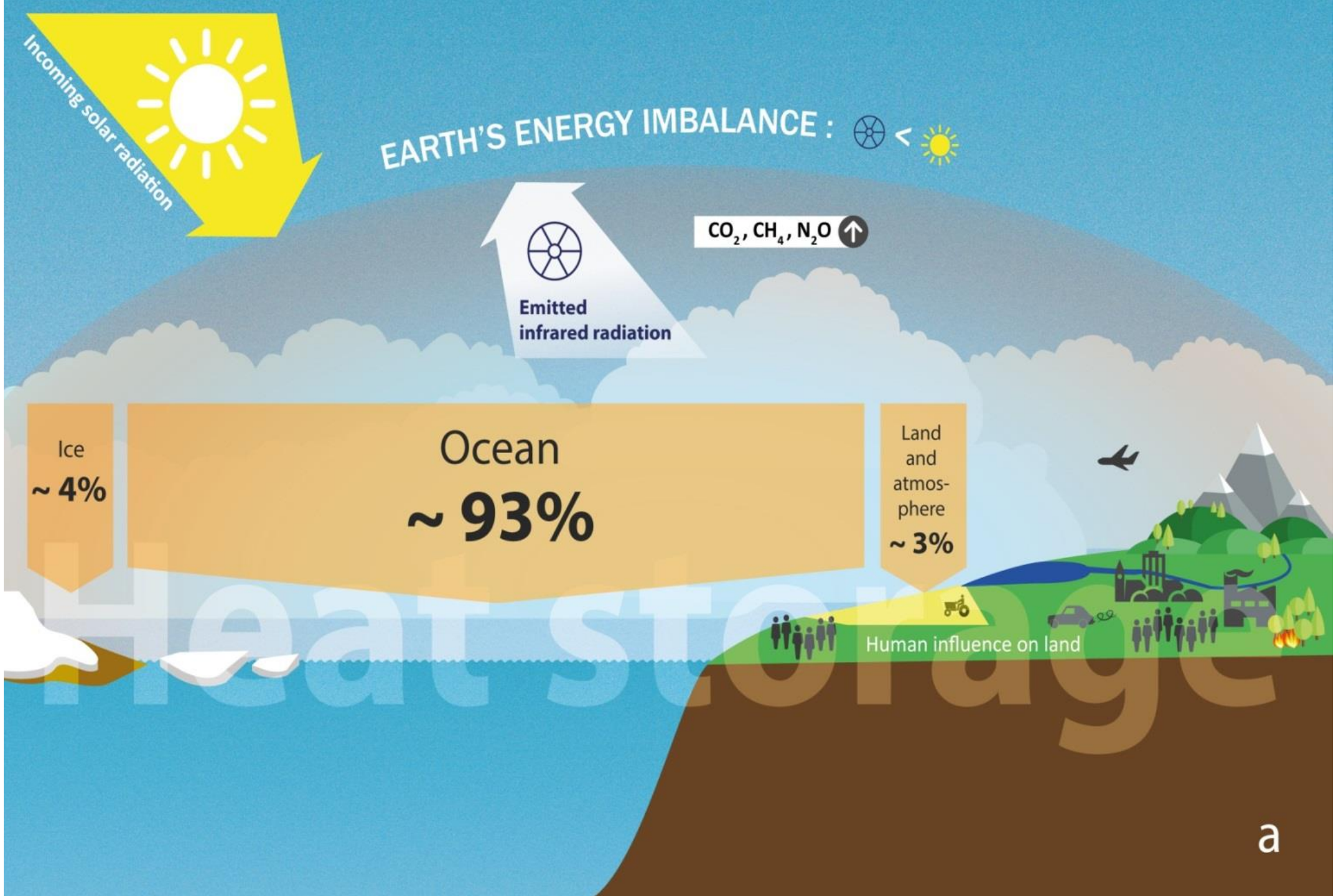
Centre d'Études Biologiques de Chizé

Ecologie et Evolution des vertébrés

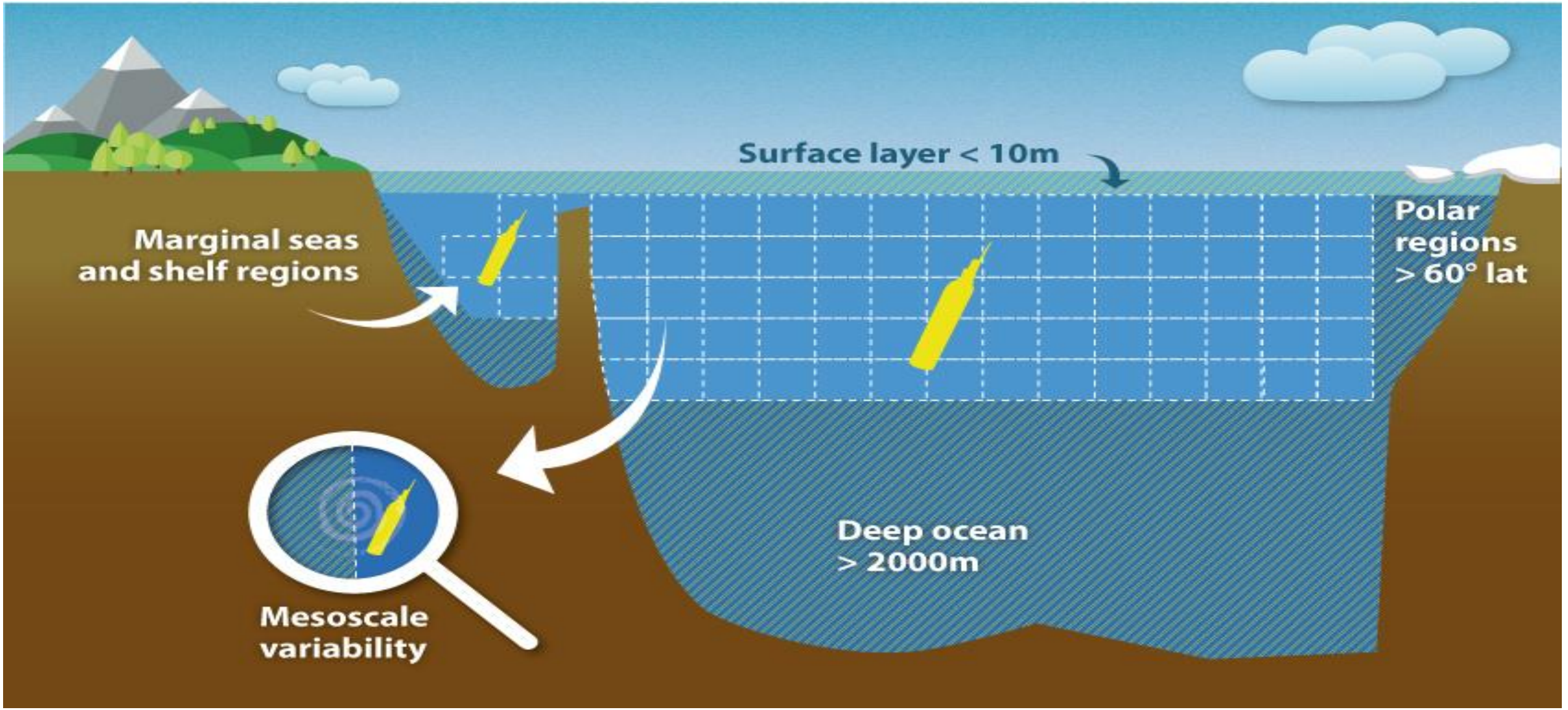
La Rochelle


Amsterdam Island
Crozet Islands
Southern Ocean
Kerguelen Island
Adélie Land

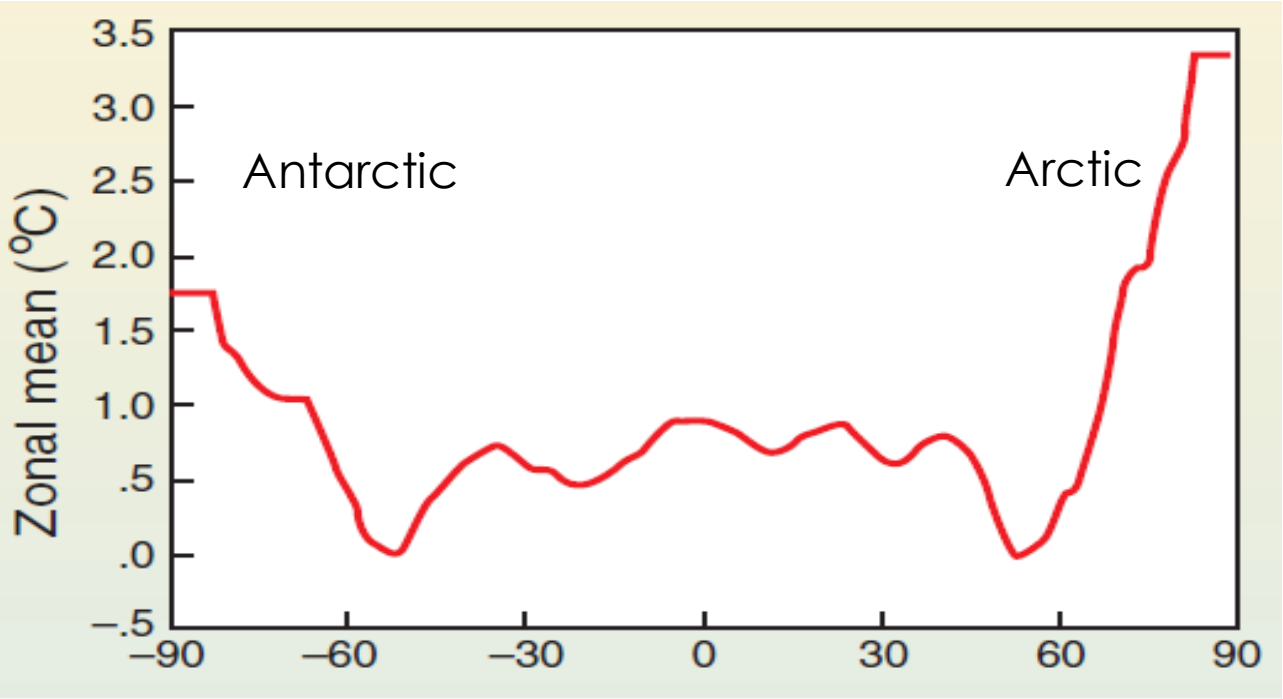

Global temperatures have increased by over 1.2°C
1850
2020

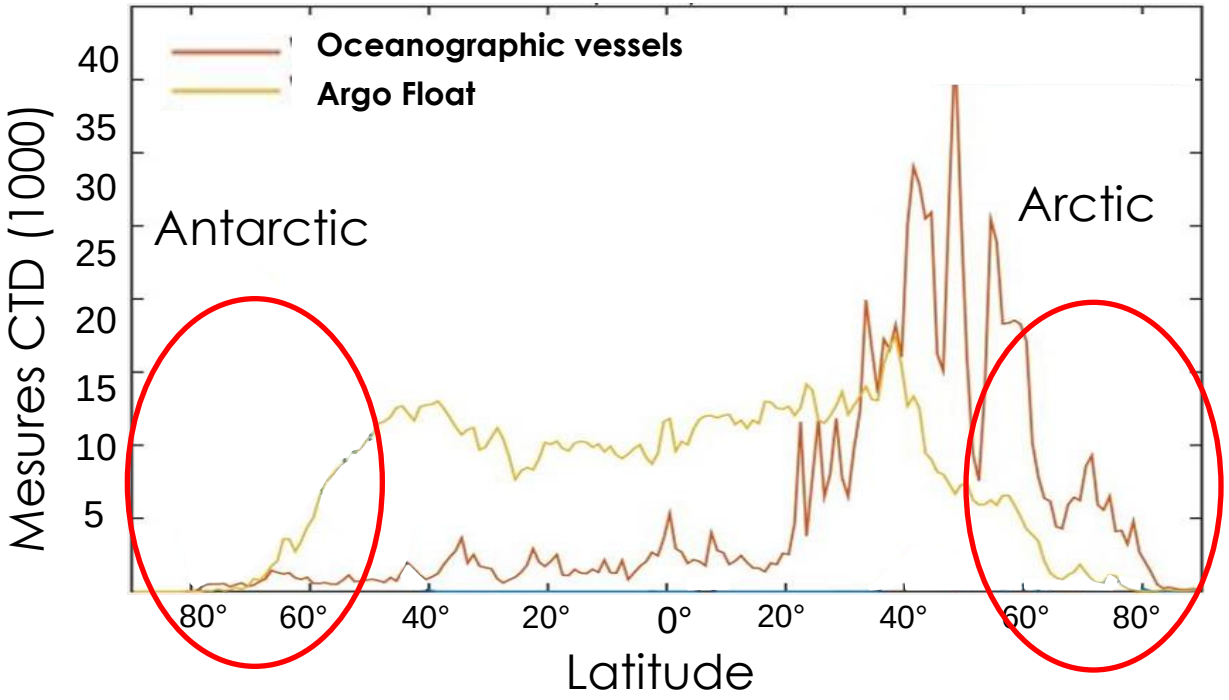

Incoming solar radiation
EARTH'S ENERGY IMBALANCE :
CO_2, CH_4, N_2O
Emitted infrared radiation
Ice ~ 4%
Ocean ~ 93%
Land and atmos-phere ~ 3%
Human influence on land
Heat storage
a

L’Océan Global:
Des zones sous observées



von Schuckmann at al., 2015, Nature Climate Change


Zonal mean (°C)
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
–.5
–90
–60
–30
0
30
60
90
Antarctic
Arctic


Oceanographic vessels
Argo Float
Mesures CTD (1000)
40
35
30
25
20
15
10
5
Antarctic
Arctic
80°
60°
40°
20°
0°
20°
40°
60°
80°
Latitude

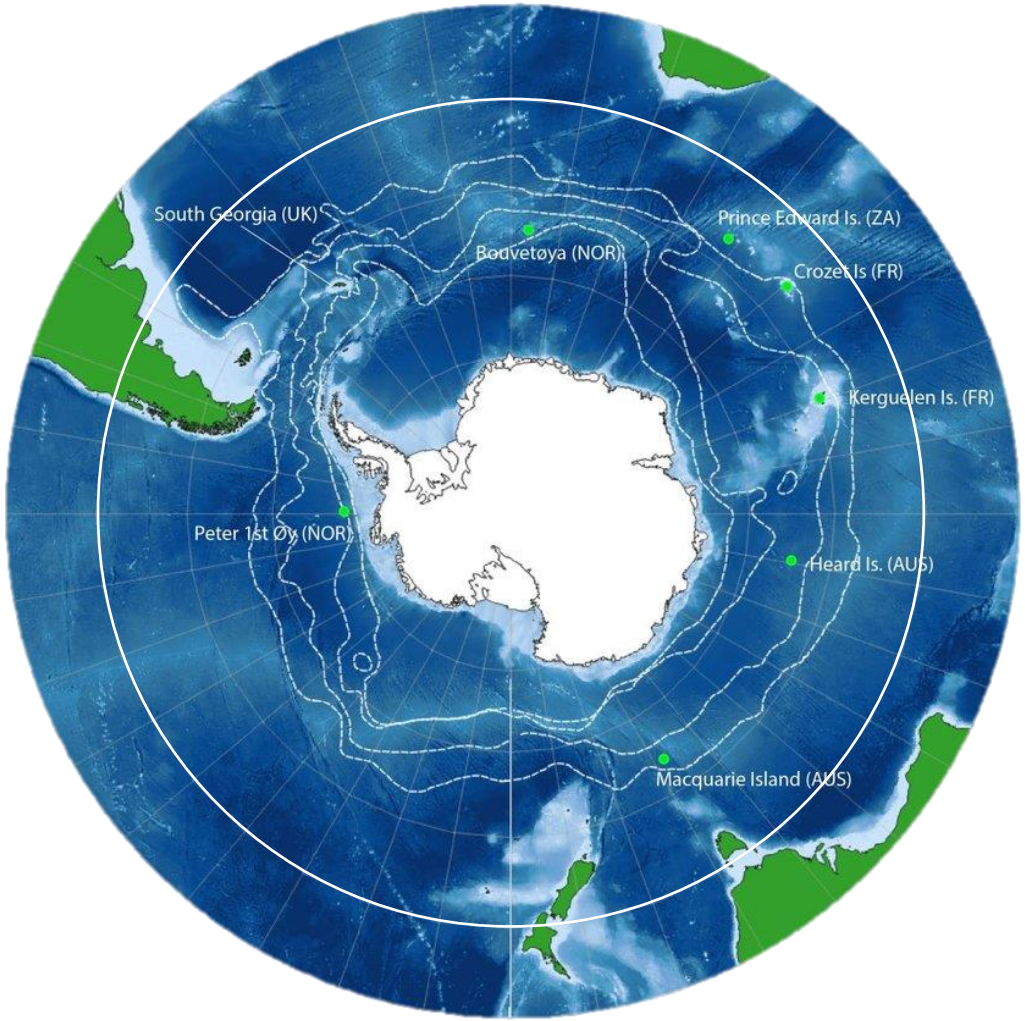
Dans un contexte de changements rapides :

Les animaux marins deviennent de nouveaux auxiliaires pour:

- observer les changements la physiques et la biologie de l'Océan

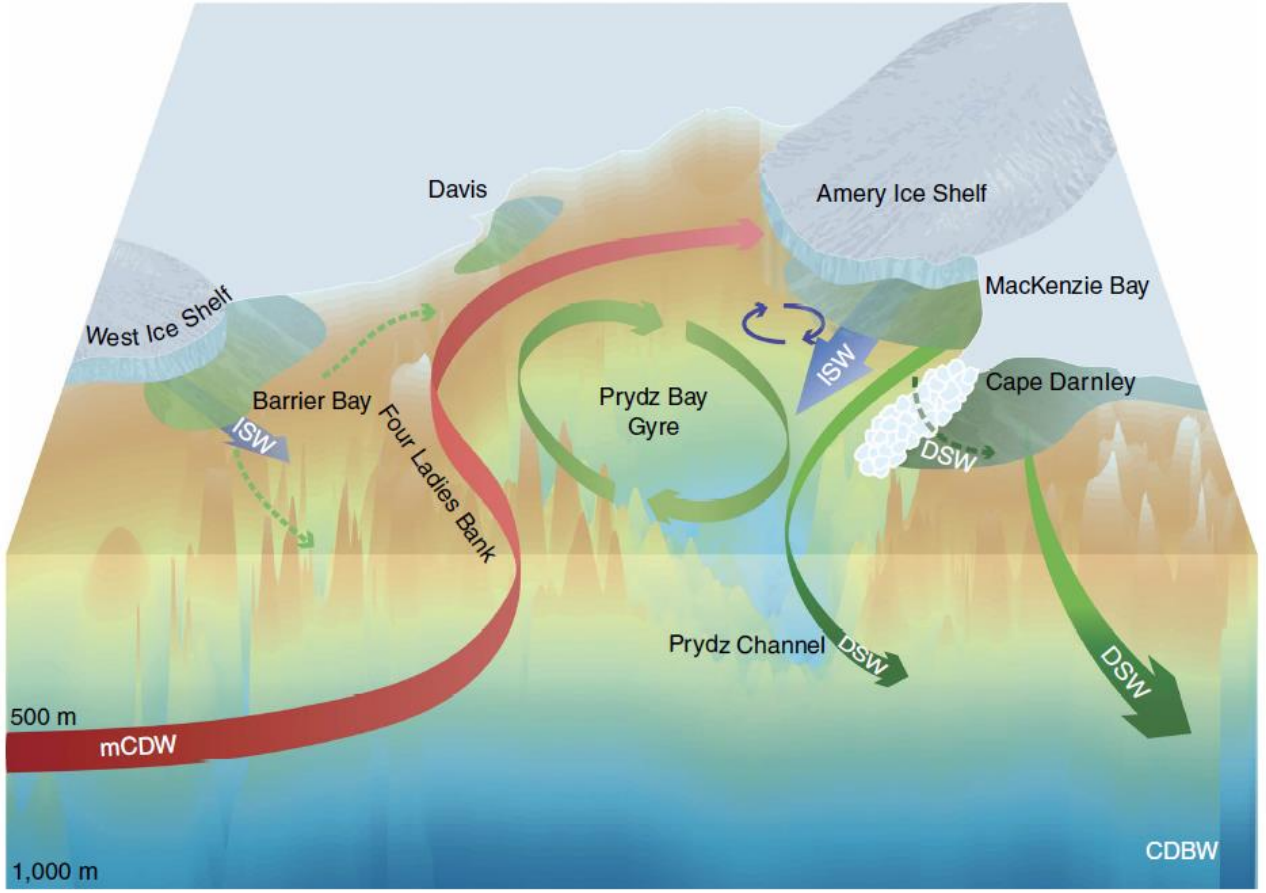
- évaluer les conséquences écologiques de ces changements.

L’océan austral



Par rapport à l’Océan global,
l’océan austral c’est :

10% de sa surface
25% de la production primaire
40 % du puit de carbone
70% du stockage de l’excès de chaleur

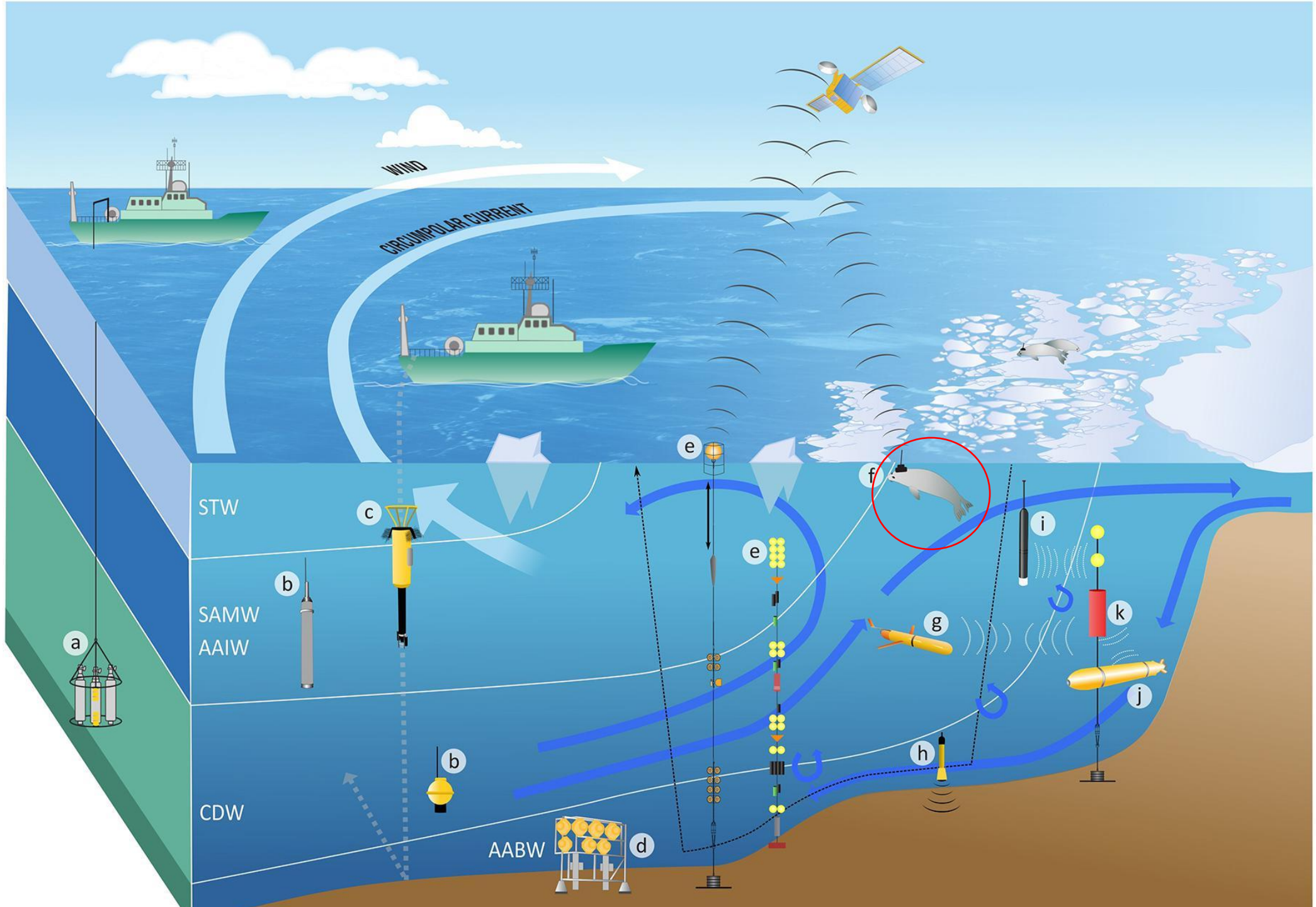


DSW= cold Dense Shelf Water

mCDW: modified Circumpolar Deep Water

Williams, G. D., Herraiz-Borreguero, L., Roquet, F., Tamura, T., Ohshima, K. I., Fukamachi, Y., Fraser, A. D., Gao, L., Chen, H., McMahon, C. R., Harcourt, R., and Hindell, M., 2016. The suppression of Antarctic bottom water formation by melting ice shelves in Prydz Bay. Nature Communication, 7. doi: 10.1038/ncomms12577

PellicheroV., Sallée J.B., Chapman C.C., Downes S.M. 2018 The southern ocean meridional overturning in the sea-ice sector is driven by freshwater fluxes. Nature Communication


WIND
CIRCUMPOLAR CURRENT
STW
SAMW
AAIW
CDW
AABW
a
b
c
d
e
f
g
h
i
j
k


TAAF
MARION DUFRESNE
MARSEILLE


Multi céréale
Mial


PETITS POIS
HARICOTS ROUGES
HARICOTS VERTS
Légumes COUSCOUS
RATATOUILLE
HARICOTS BLANCS

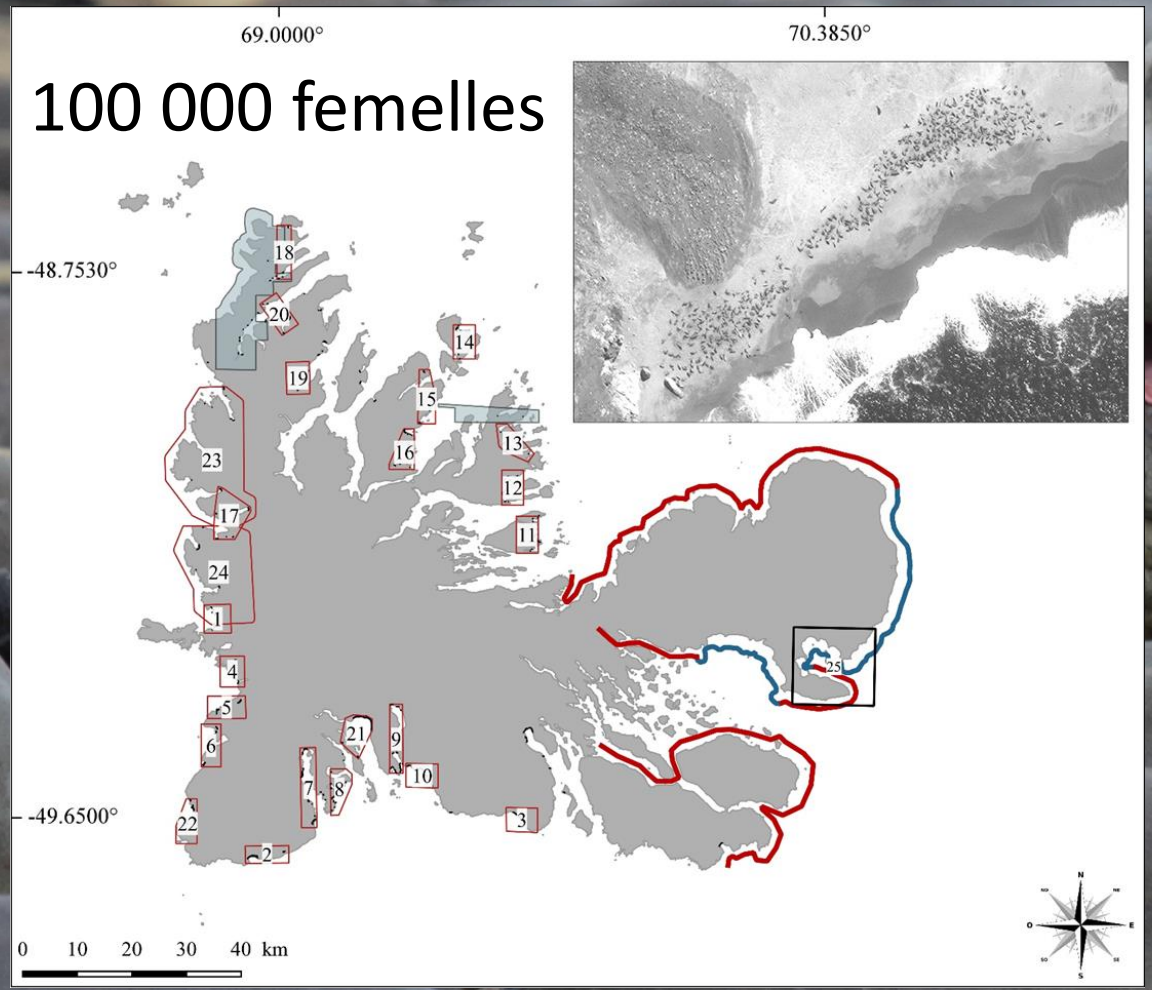

DES BONBONS
OU UN

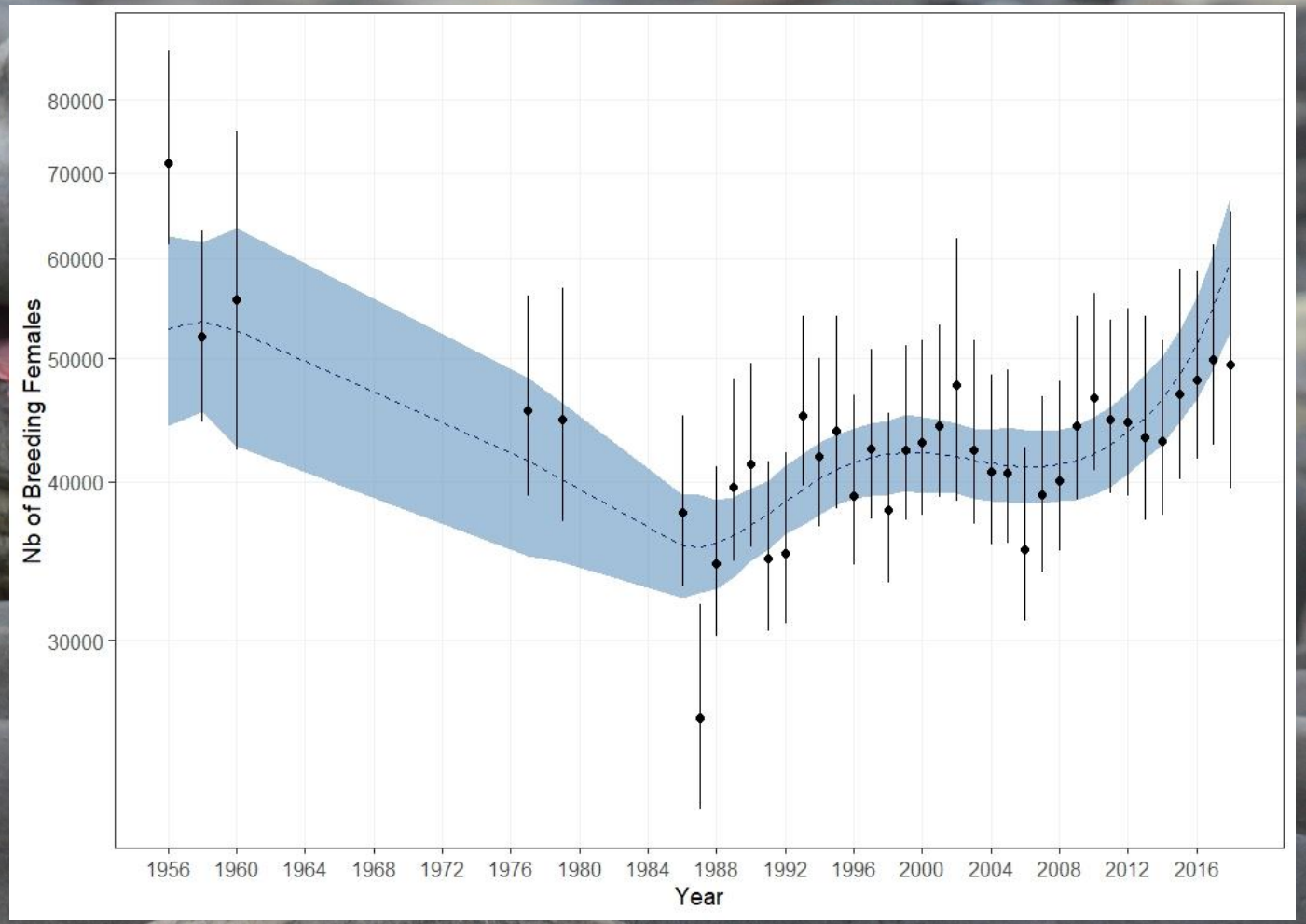
Mirounga leonina:
un phoque d'exception

L'éléphant de mer le plus grand des phoques

- male 2-3 tonnes pour 4,3 m, 10-11 ans, 14 ans
- femelles 300-600 kg pour 2,3 m, 3-4 ans, 18 ans

100 000 femelles





Biotelemetry : Argos Transmitted (2-4 profiles/day), Real time

- Depth
- Temperature (0.02°C)
- Salinity (1HZ, 0.03 PSU)
- (Fluorescence)
- Dissolved oxygen

Biologging : Archived (the tag need to be recovered)

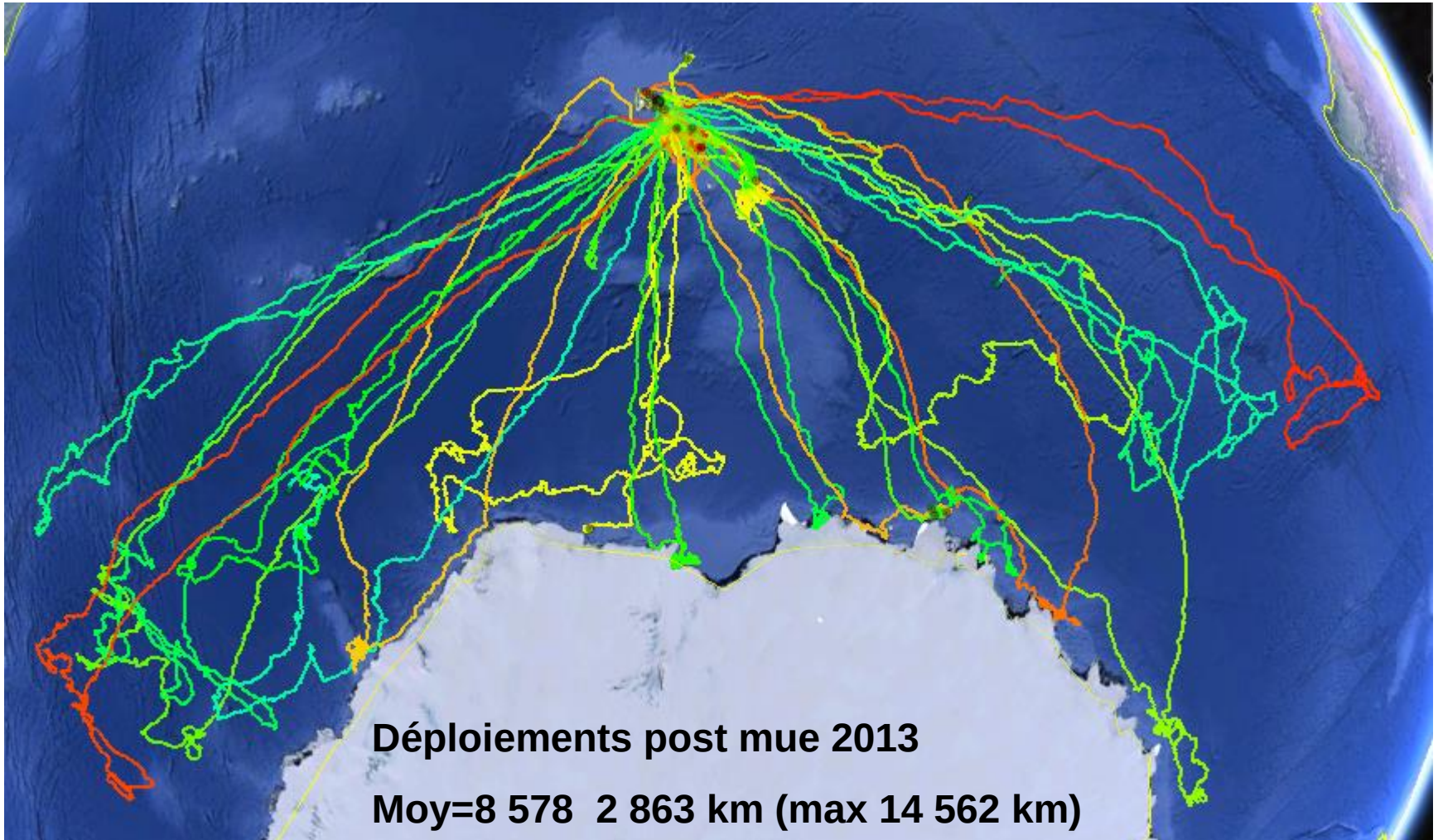
- Depth (1Hz)
- Temperature (1Hz, 0.02°C)
- Salinity (1Hz, 0.03 PSU)
- Fluorescence, (1Hz 4/profiles per day)
- Dissolved oxygen (1 Hz, 4 profiles per day)
- Light (1 Hz)
- Accelerometer (12Hz)

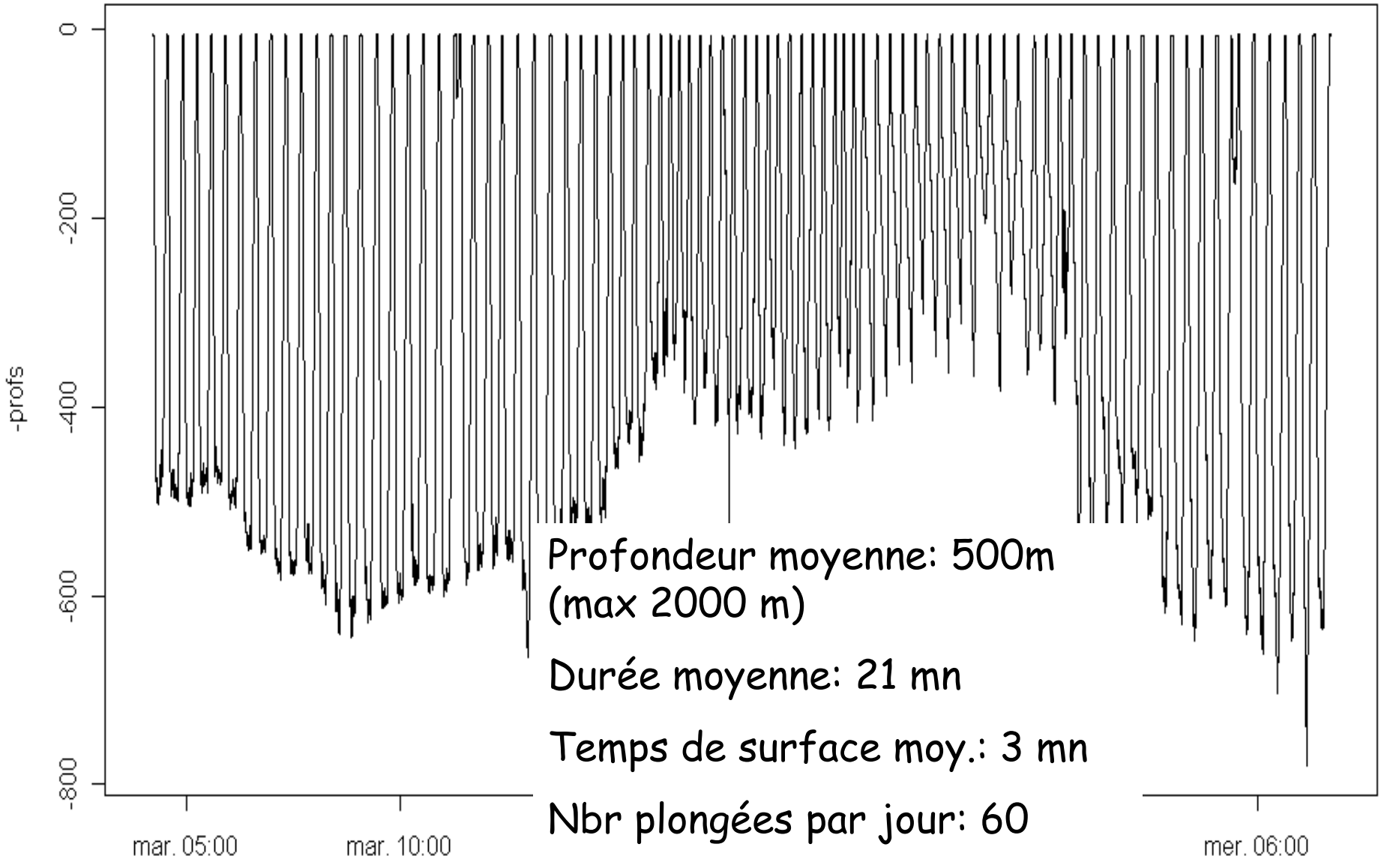
J	F	M	A	M	J	J	A	S	O	N	D

Mue **Reproduction**

- 10 mois en mer

- 2 mois à terre pour se reproduire et muer





Profondeur moyenne: 500m (max 2000 m)

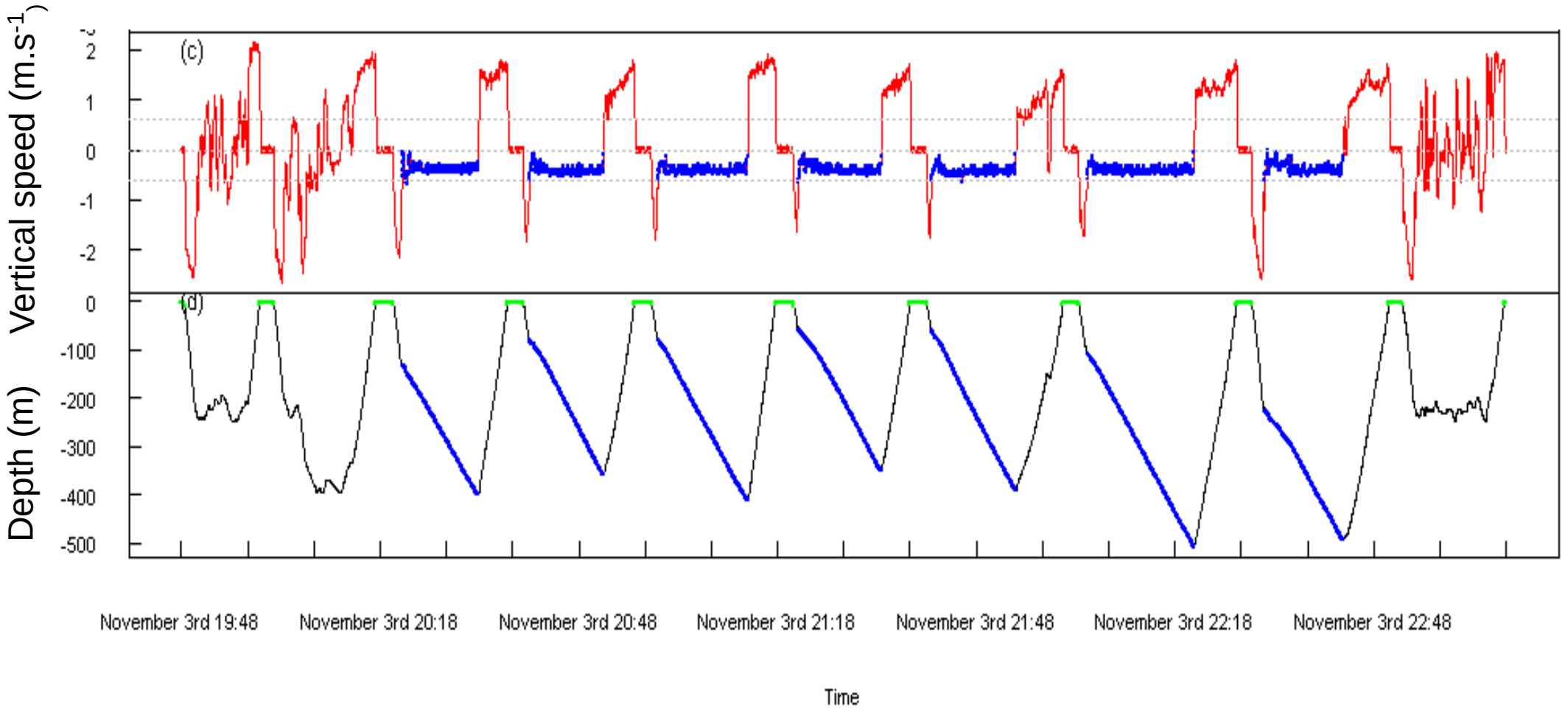
Durée moyenne: 21 mn

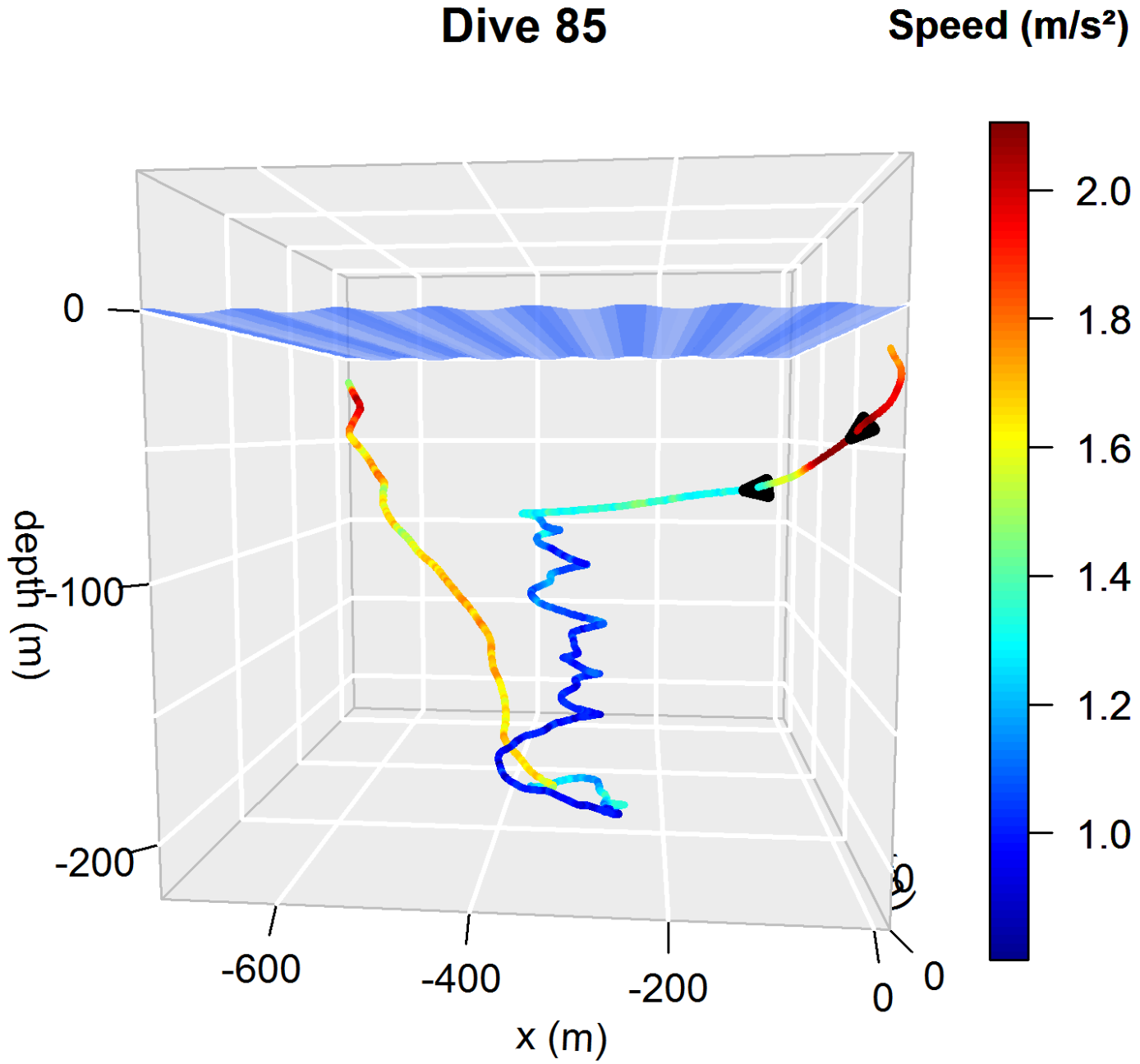
Temps de surface moy.: 3 mn

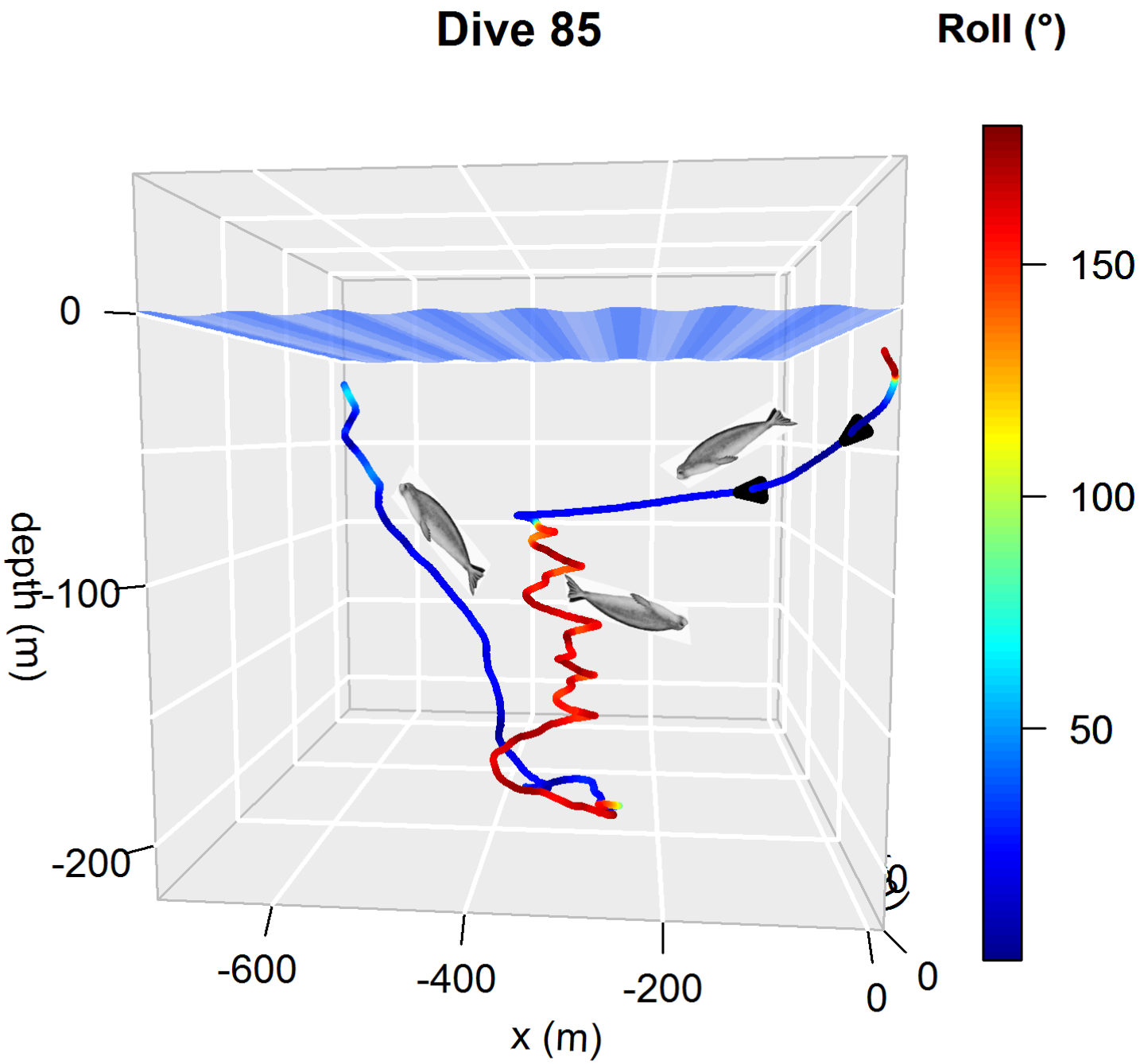
Nbr plongées par jour: 60

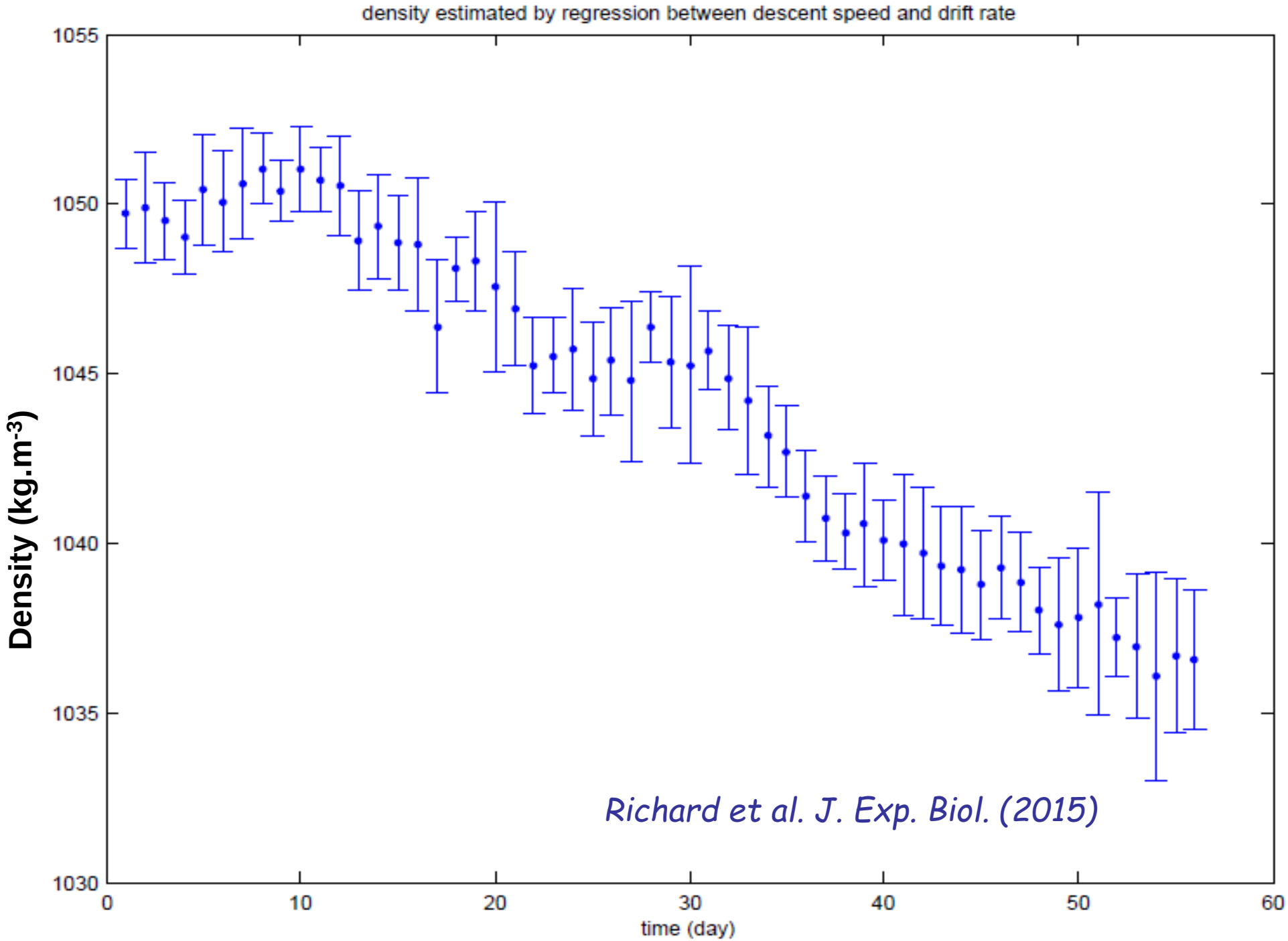
0-2 km entre plongées

Evaluer le changement de la flottabilité (condition) des éléphants de mer
Les plongées de dérive passive




Dive 85
Speed (m/s²)
2.0
1.8
1.6
1.4
1.2
1.0
0
-100
-200
depth (m)
-600
-400
-200
0
x (m)
0

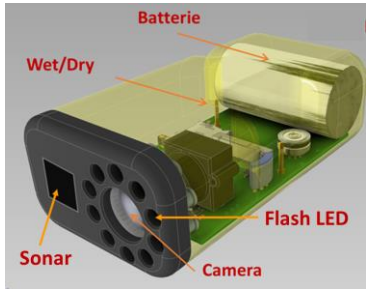

Dive 85
Roll (°)
150
100
50
0
-100
-200
depth (m)
-600
-400
-200
0
0
0
x (m)


density estimated by regression between descent speed and drift rate
Density (kg.m-3)
1055
1050
1045
1040
1035
1030
0
10
20
30
40
50
60
time (day)
Richard et al. J. Exp. Biol. (2015)

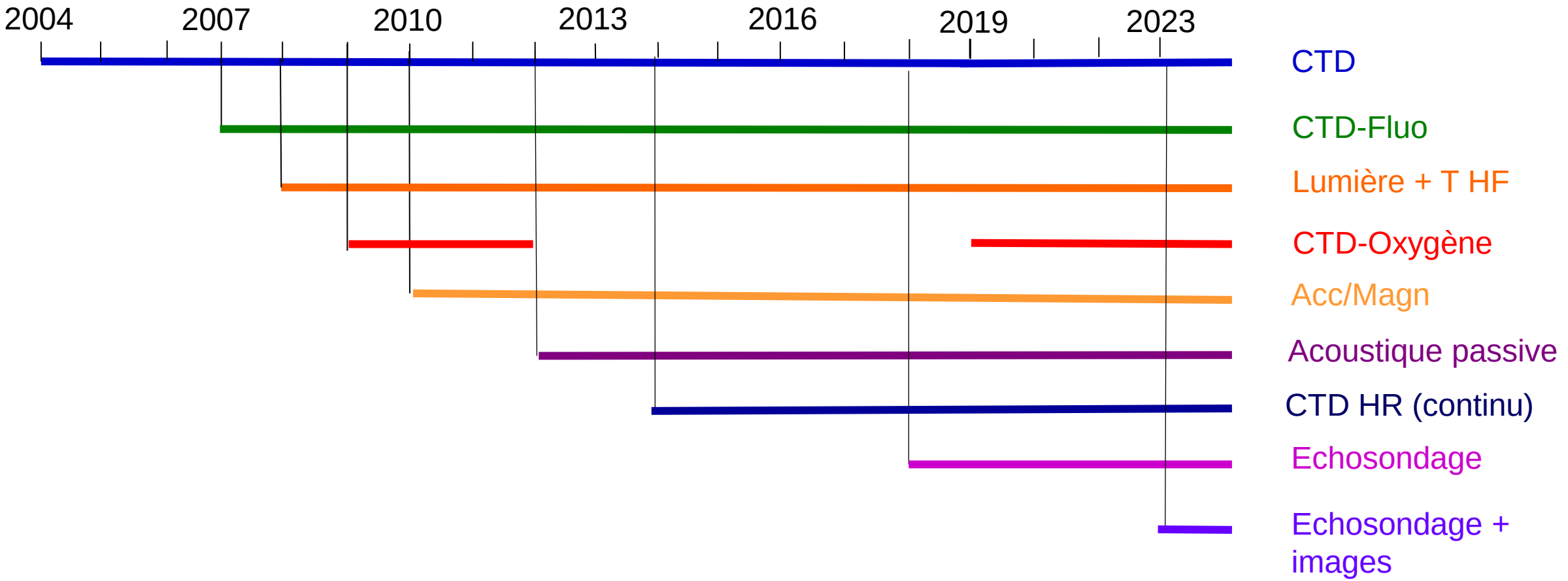
CTD-Fluo + lumière

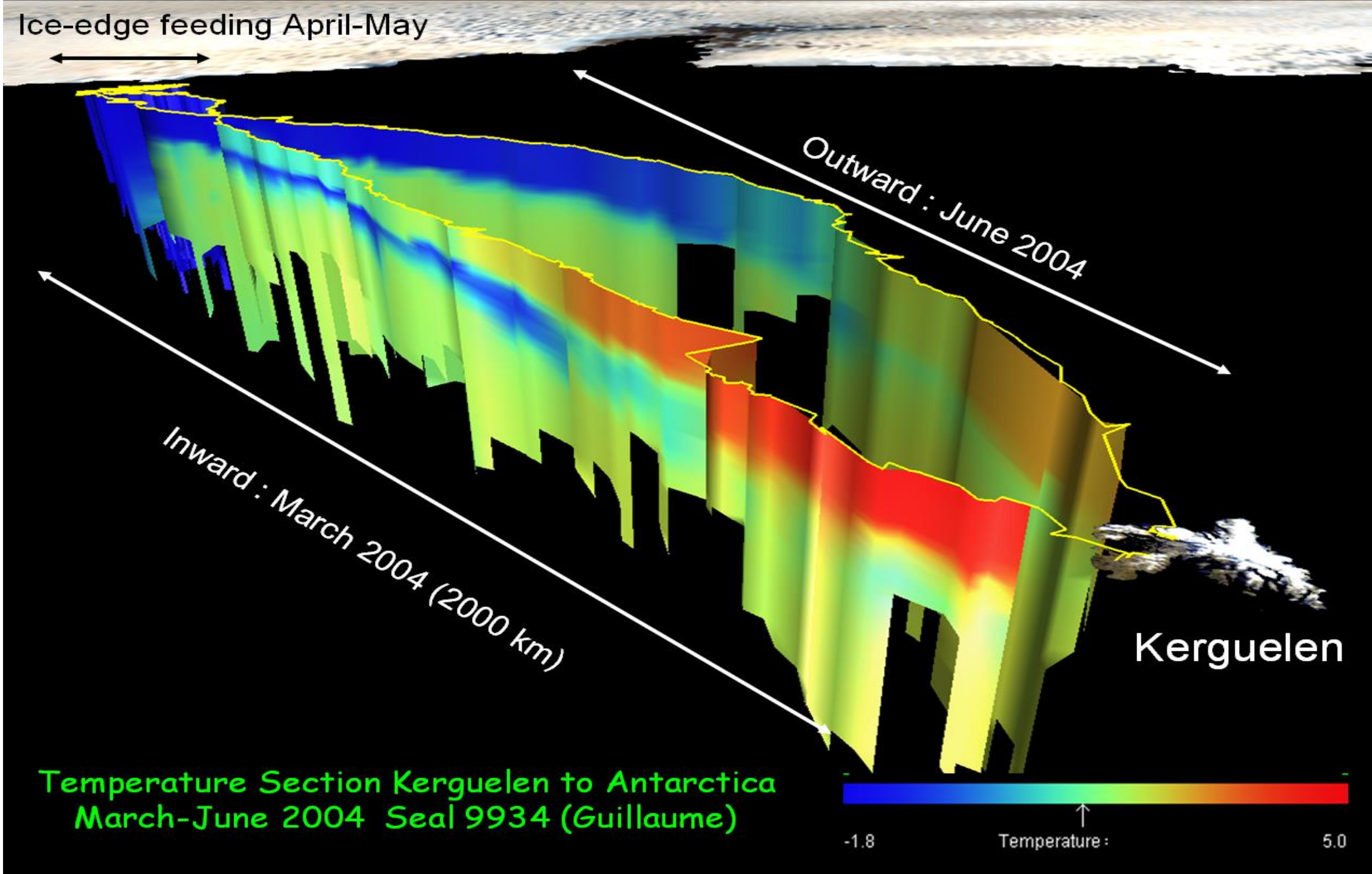
CTD-Oxygène

CTD-acoustique passive



Echosondage + images





MERCATOR OCEAN INTERNATIONAL

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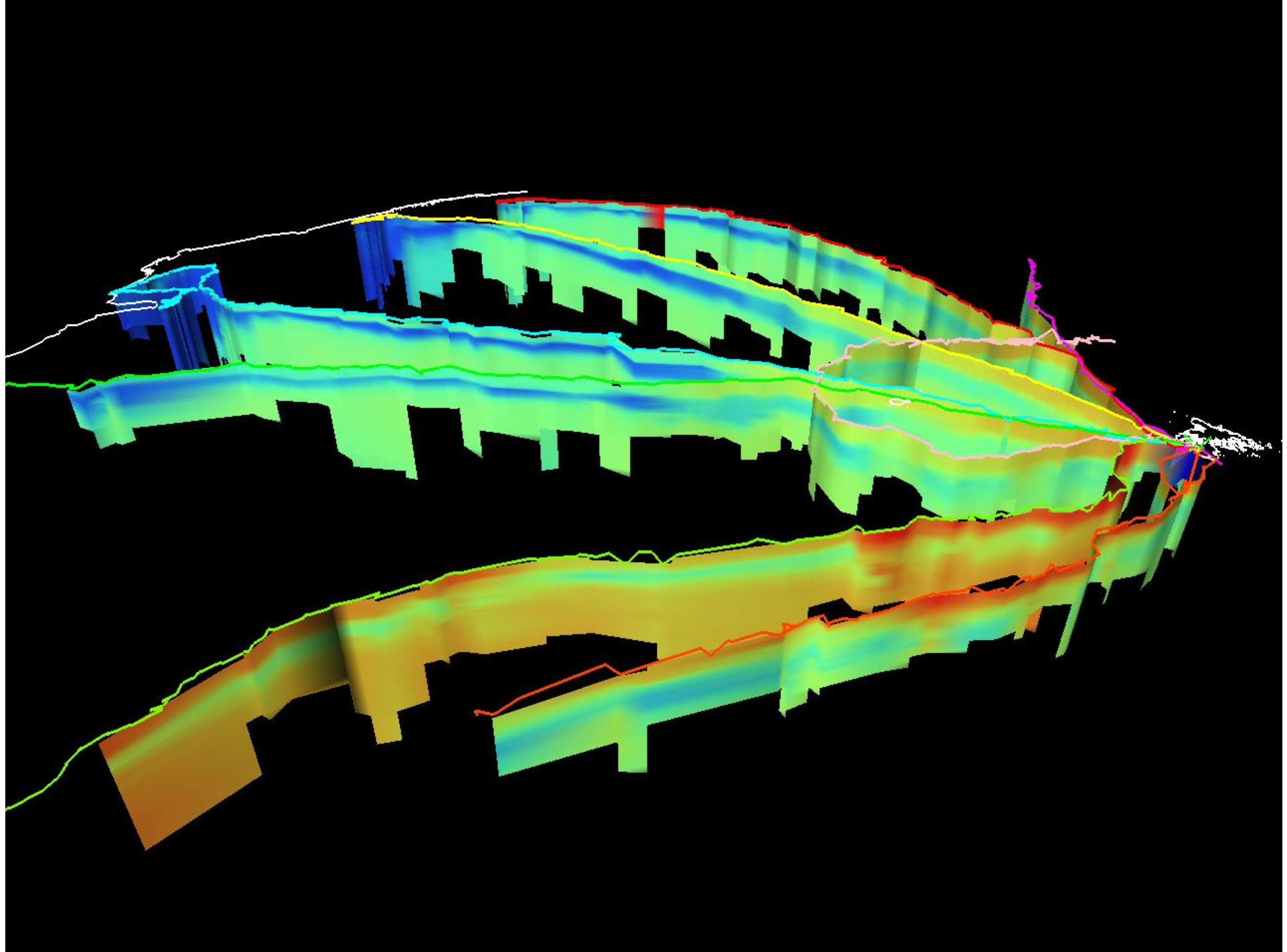
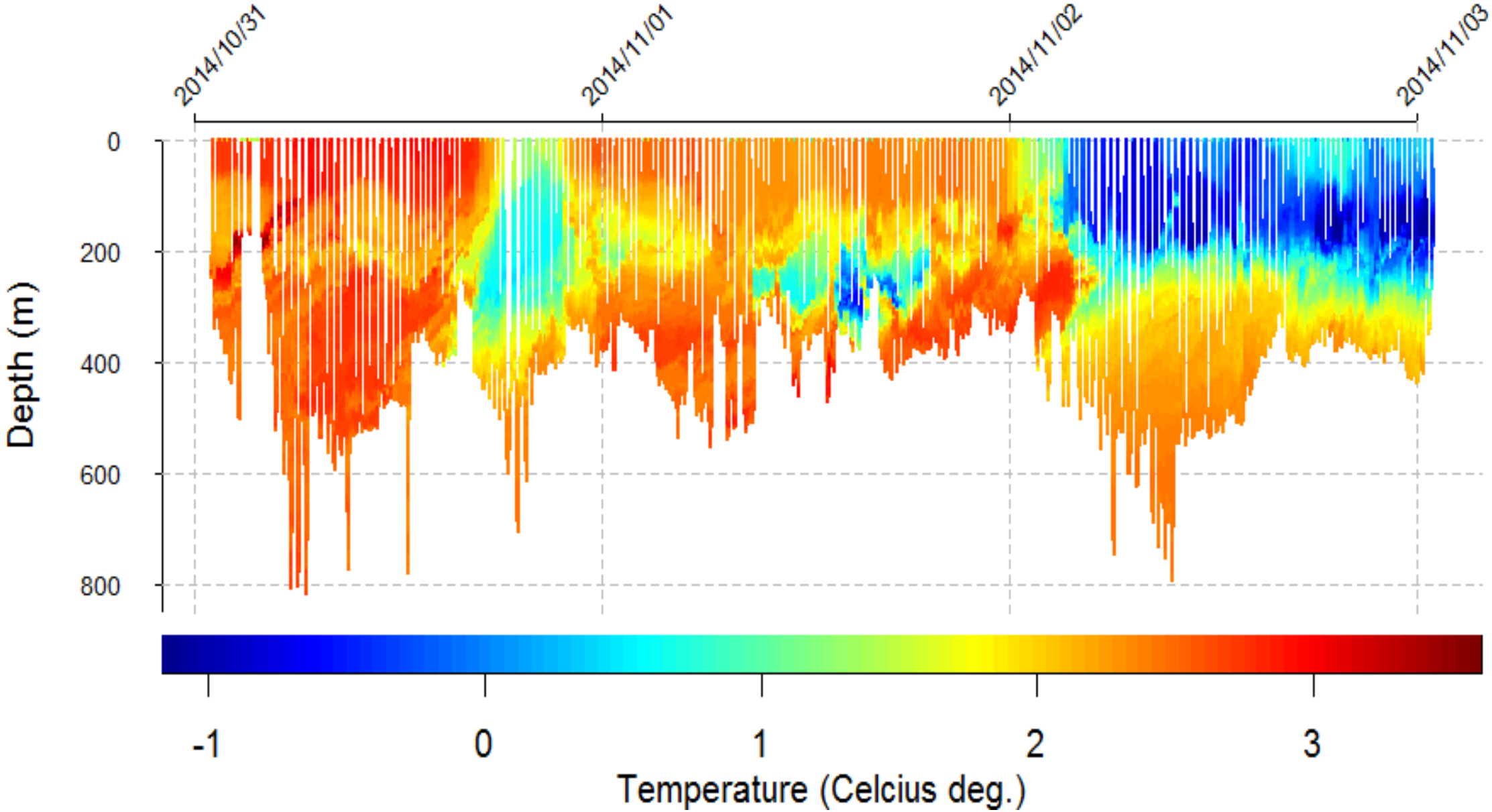
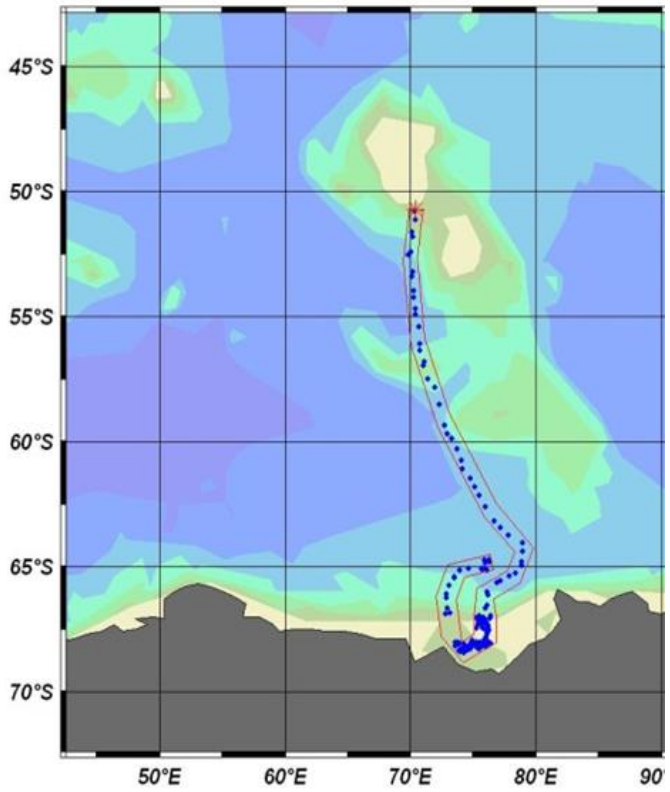
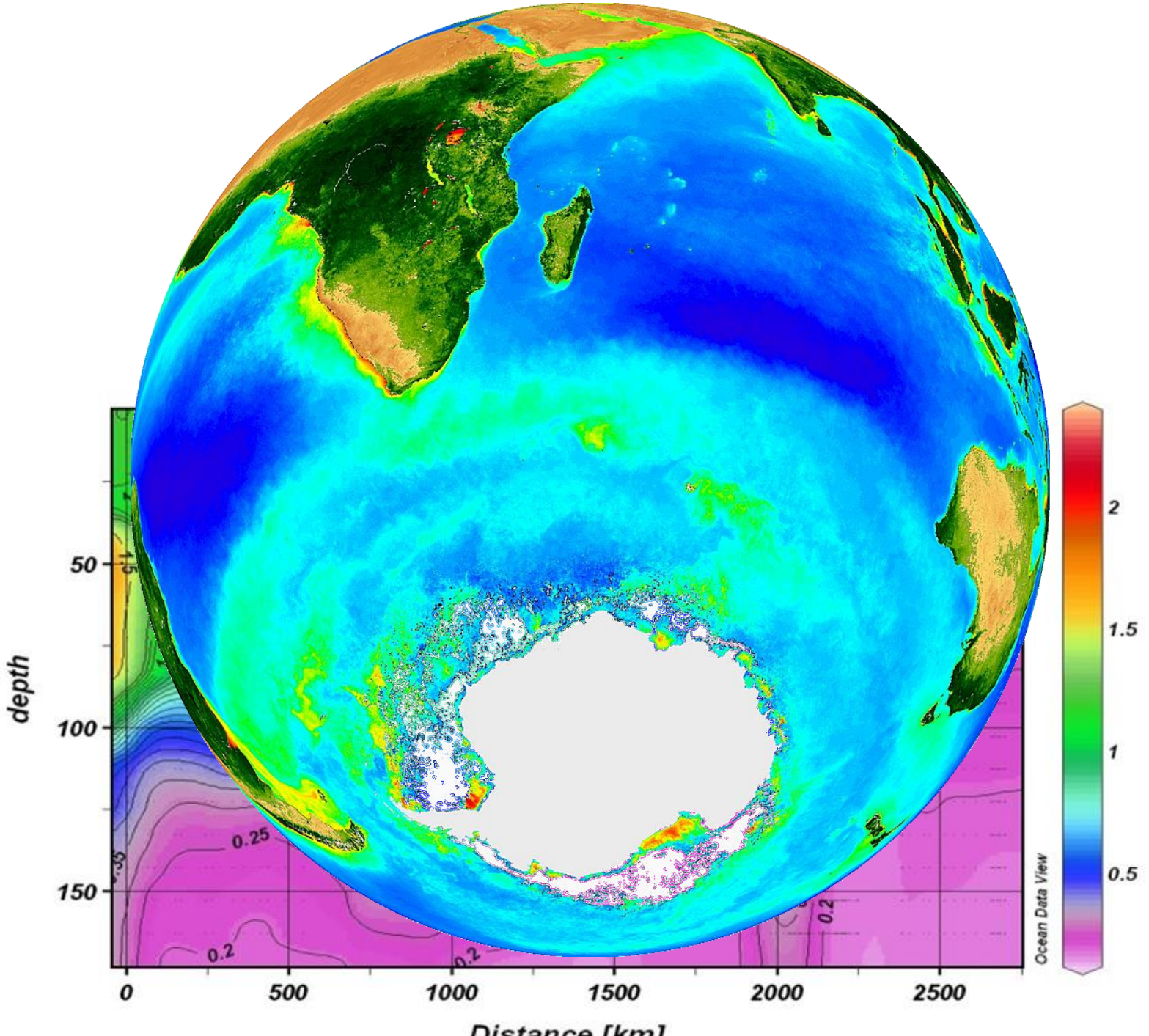
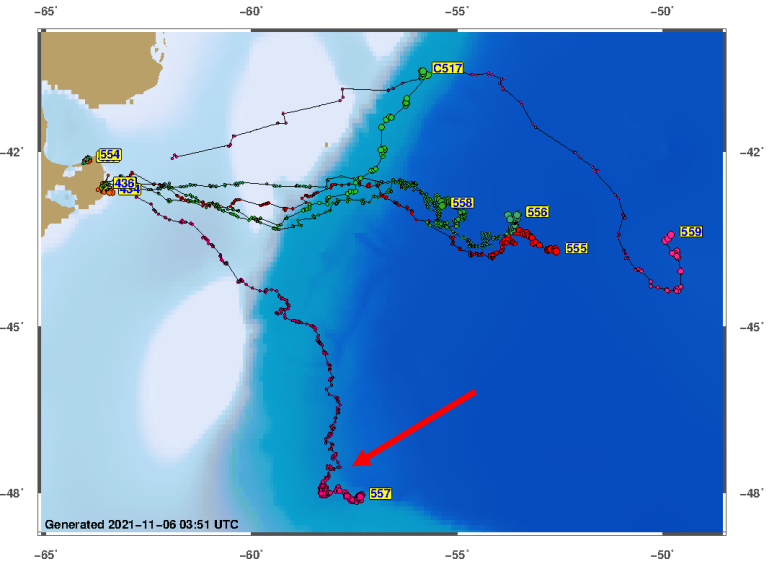
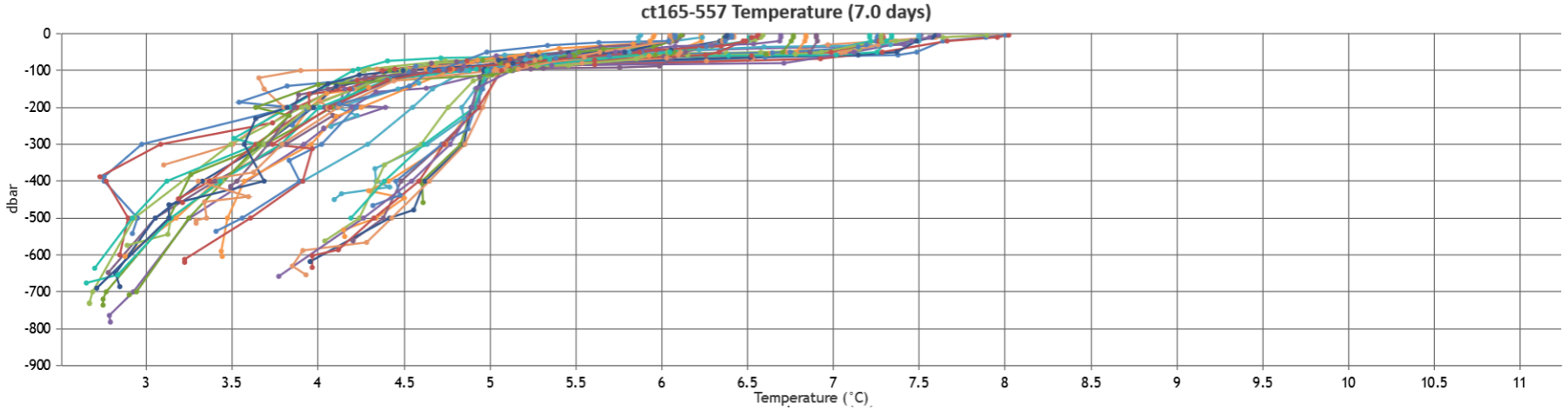


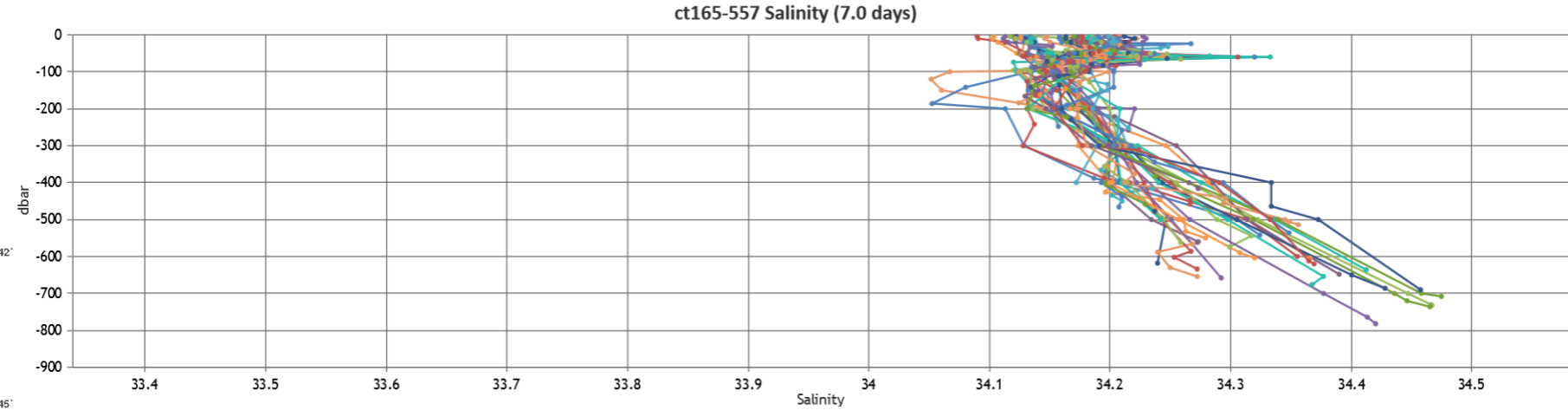

2014/10/31
2014/11/01
2014/11/02
2014/11/03
0
200
400
600
800
Depth (m)
-1
0
1
2
3
Temperature (Celcius deg.)

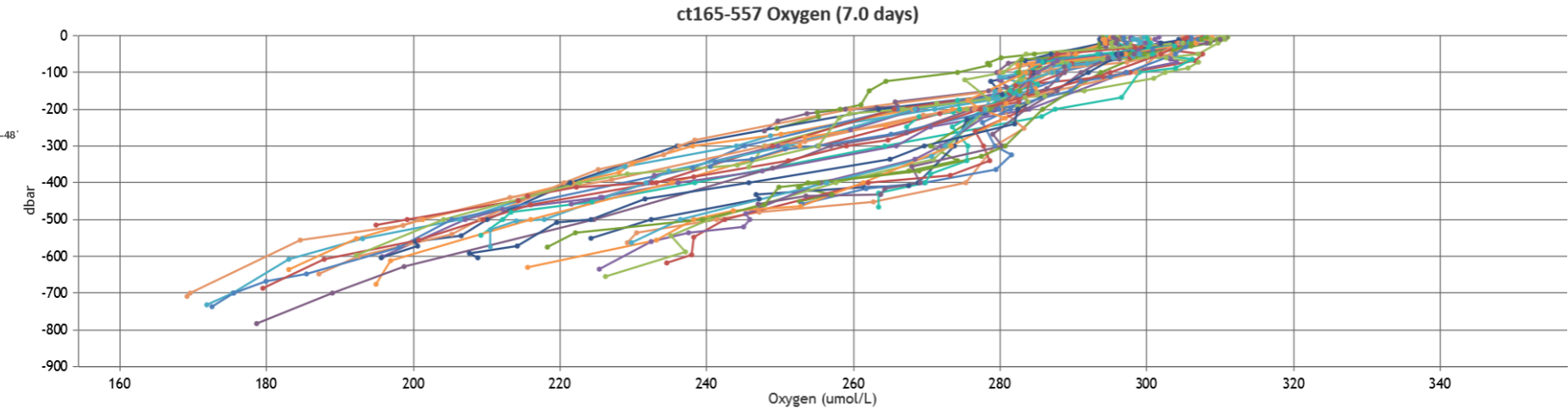

45°S
50°S
55°S
60°S
65°S
70°S
50°E
60°E
70°E
80°E


depth
50
100
150
0
500
1000
1500
2000
2500
Distance [km]
0.25
0.2
0.2
0.2
Ocean Data View
2
1.5
1
0.5



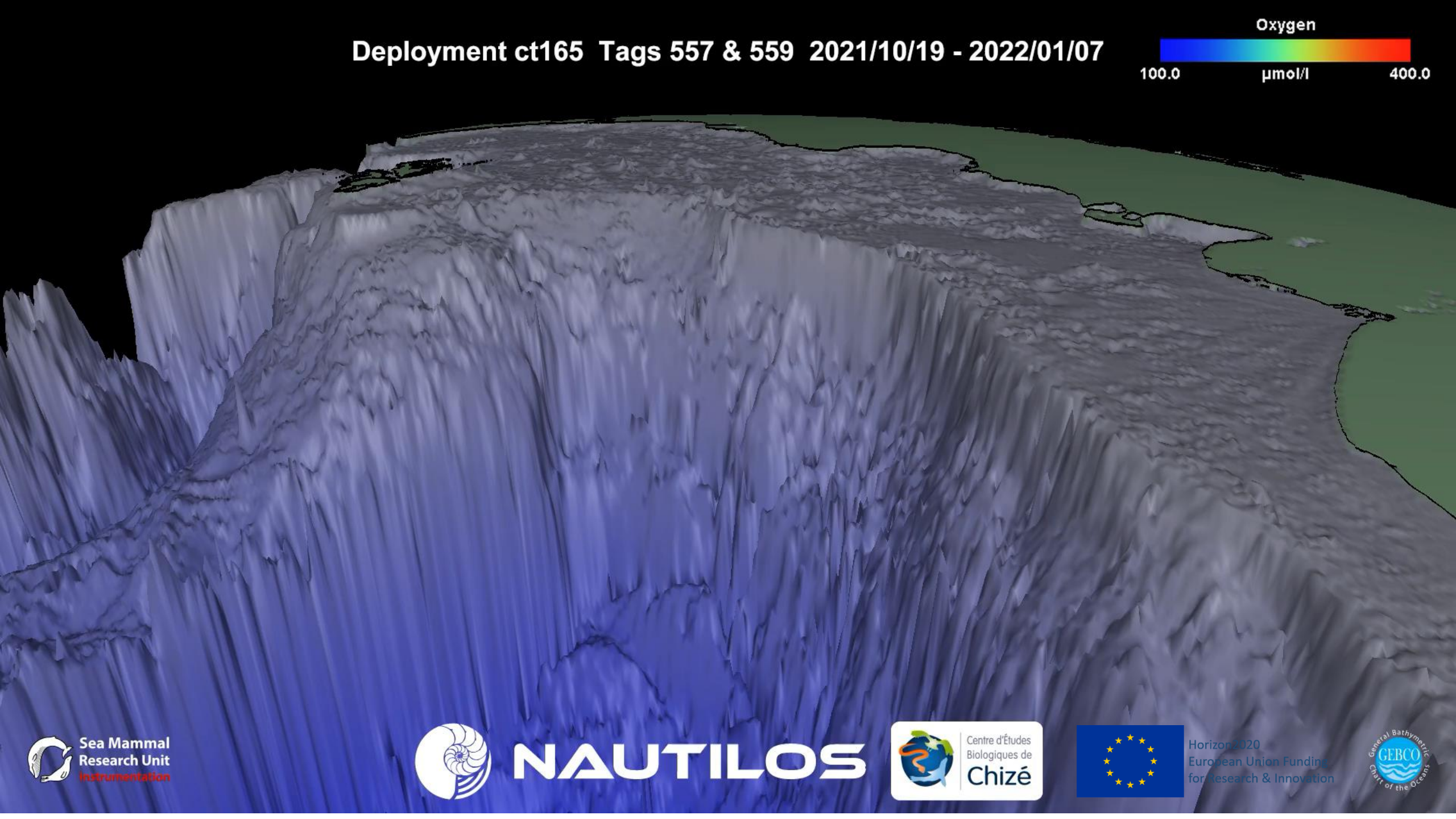






Horizon2020
European Union Funding
for Research & Innovation

NAUTILOS


Deployment ct165 Tags 557 & 559 2021/10/19 - 2022/01/07
Oxygen
100.0
µmol/l
400.0
Sea Mammal
Research Unit
Instrumentation
NAUTILOS
Centre d'Études
Biologiques de
Chizé
Horizon2020
European Union Funding
for Research & Innovation
General Bathymetric
GEBCO
Chart of the Oceans

Dissolved oxygen

2021/10/19 - 2022/01/07

Oxygen

100.0 µmol/l 400.0

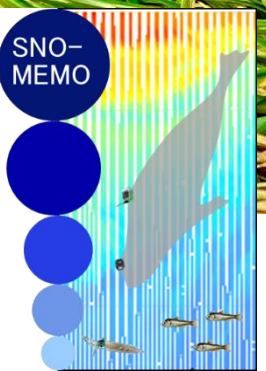
Sea Mammal Research Unit
Instrumentation

NAUTILOS

Centre d'Études Biologiques de Chizé

General Bathymetric Chart of the Oceans
GEBCO

> 850 Balises déployées depuis 2004 dans le cadre d'une collaboration franco-australienne sur les éléphants de mer et les phoques de Weddell

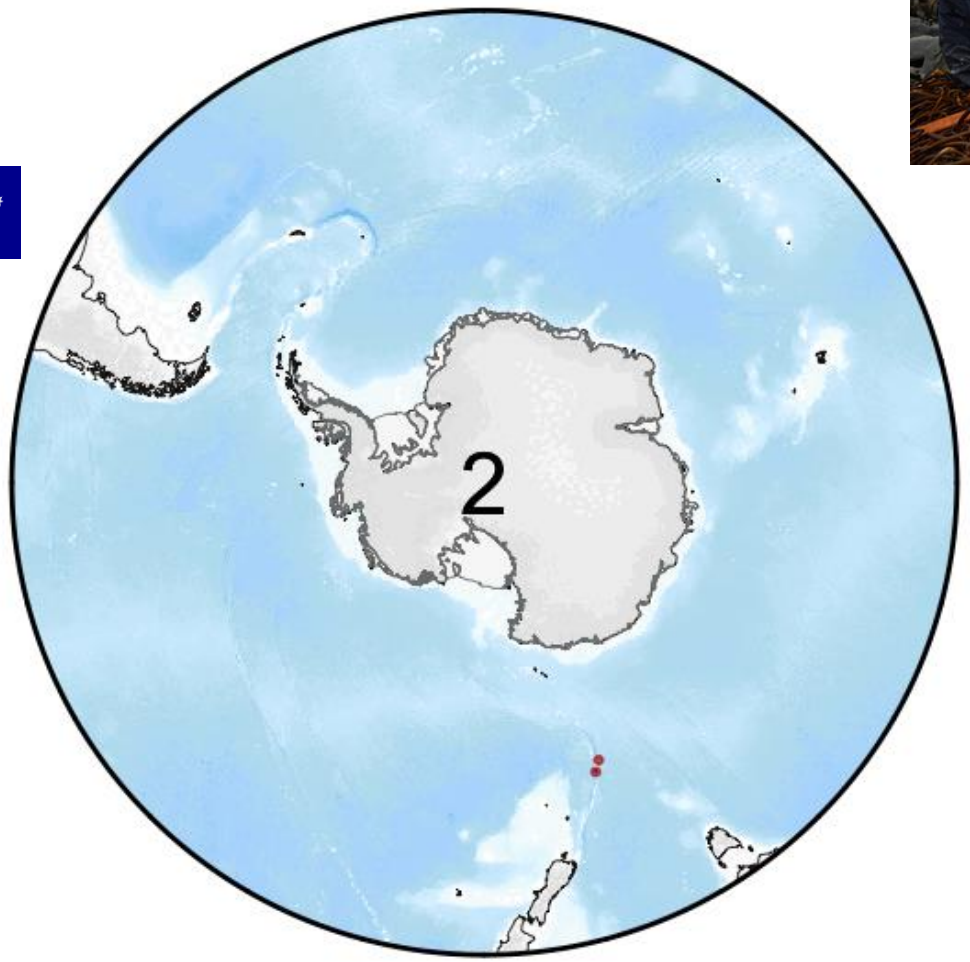


IMOS

The Global Ocean Observing System

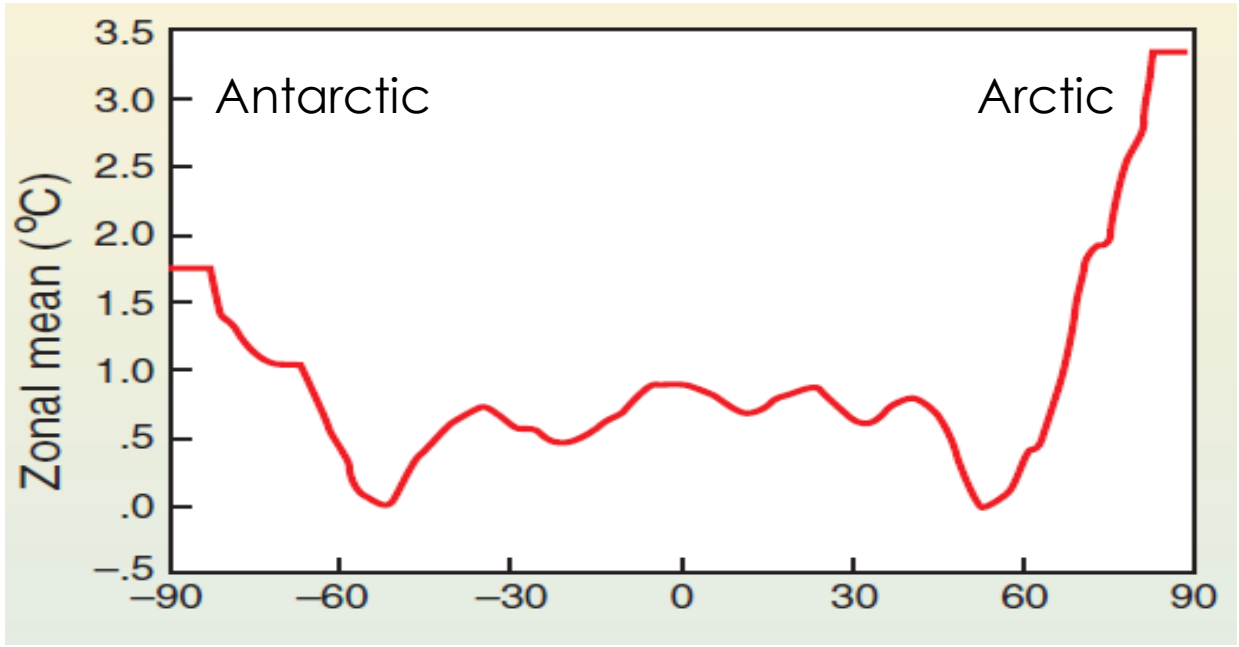
ANIBOS

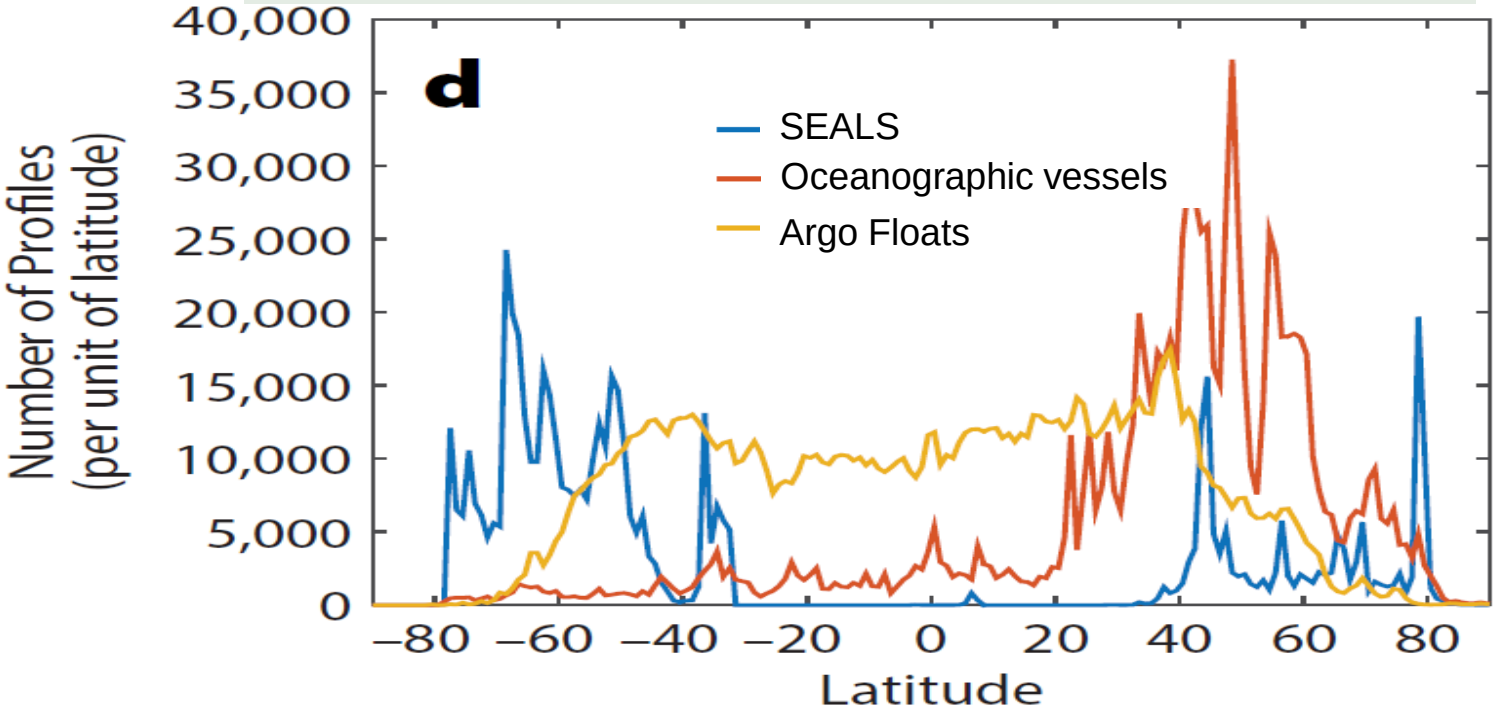
Date: 2004 January

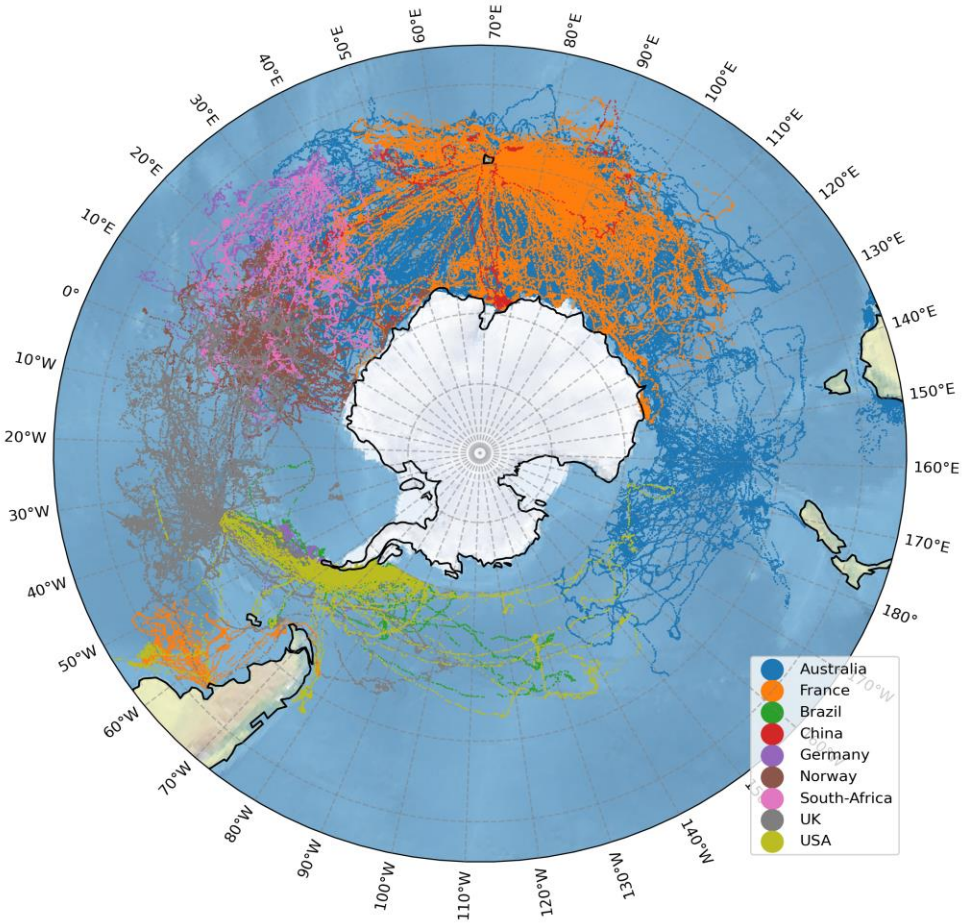


80 % of the T/S profiles au sud de 60°S
95 % of the T/S profiles associés à la banquise antarctique

species
- southern elephant seal
- Weddell seal

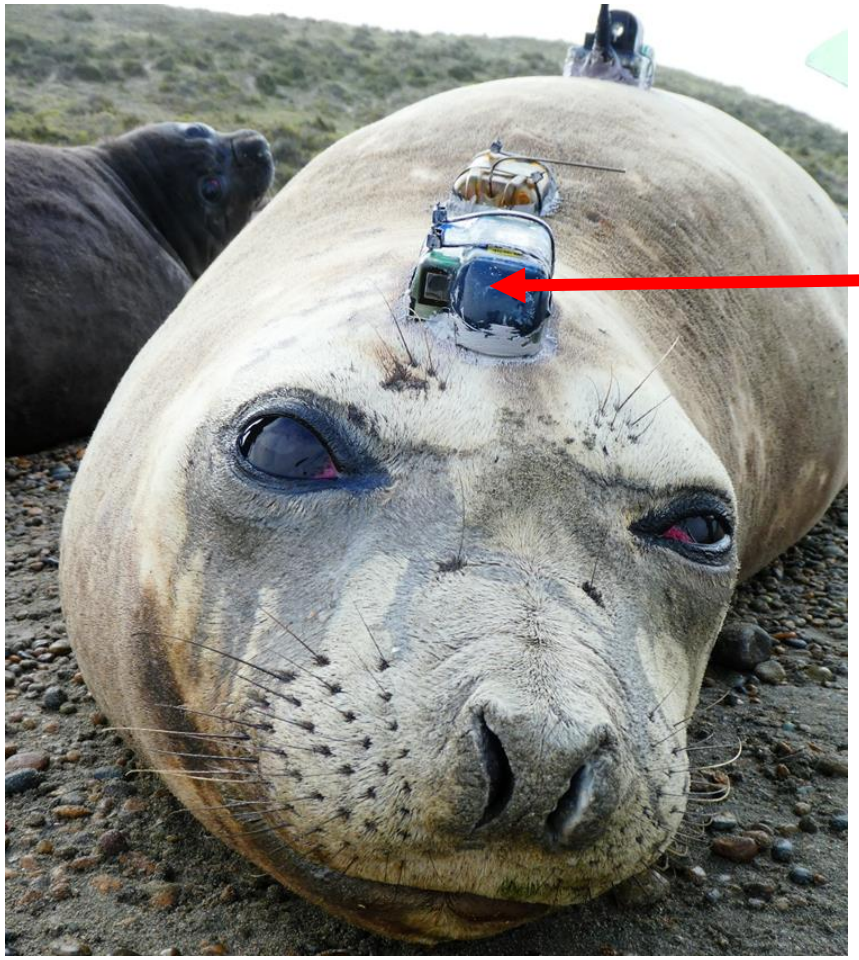

Antarctic
Arctic
Zonal mean (°C)
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
–.5
–90
–60
–30
0
30
60
90


d
SEALS
Oceanographic vessels
Argo Floats
Number of Profiles
(per unit of latitude)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
–80 –60 –40 –20 0 20 40 60 80
Latitude


Australia
France
Brazil
China
Germany
Norway
South-Africa
UK
USA

meop.net

Un même capteur permet d'étudier des questions très différentes : cas de l'acoustique passive

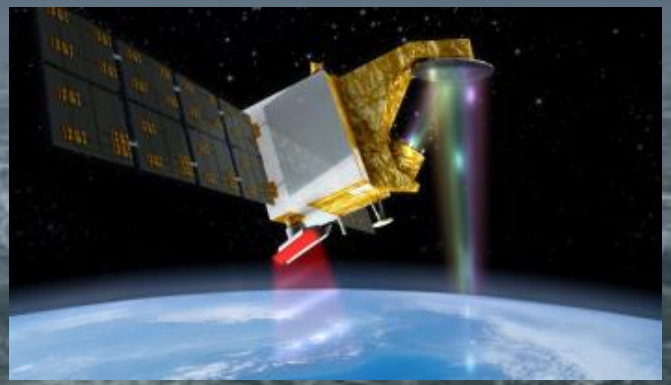


Hydrophone

Accelerometer,
Magnetometer,

Pressure sensor,
GPS,
Light sensor,
Temperature sensor

Wind and sea-state



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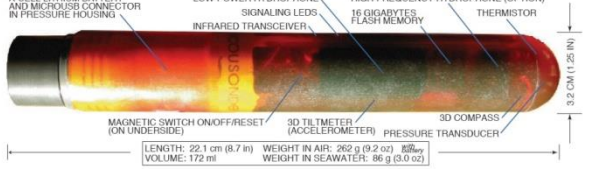
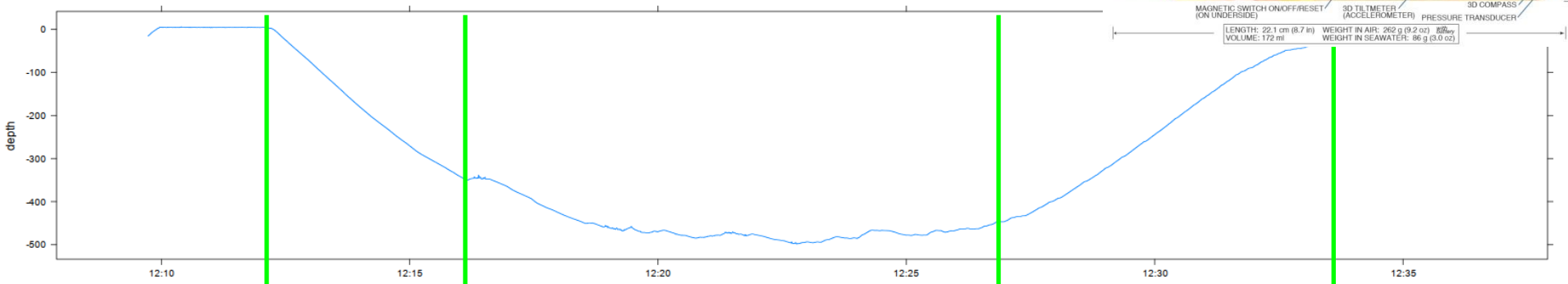
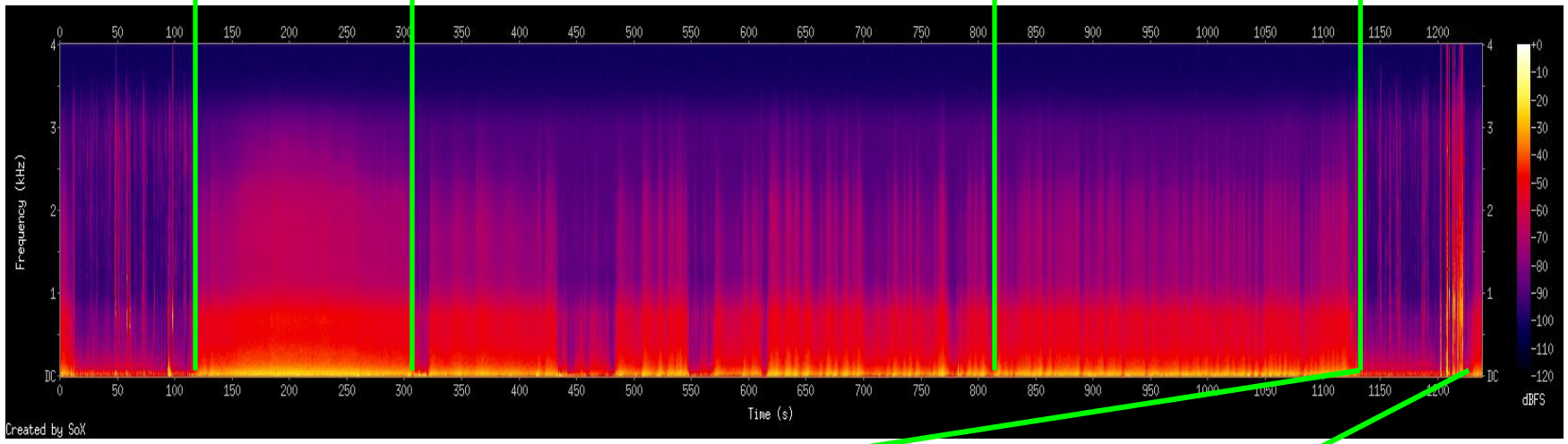
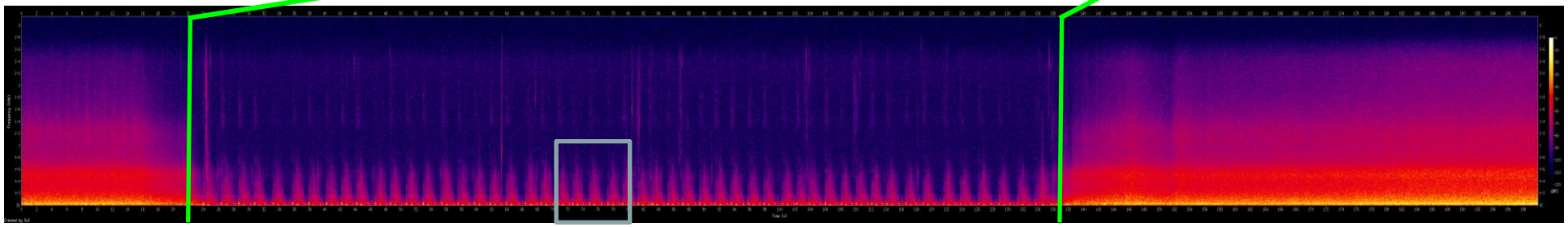
(Chineese-French Ocean SAT-2018)

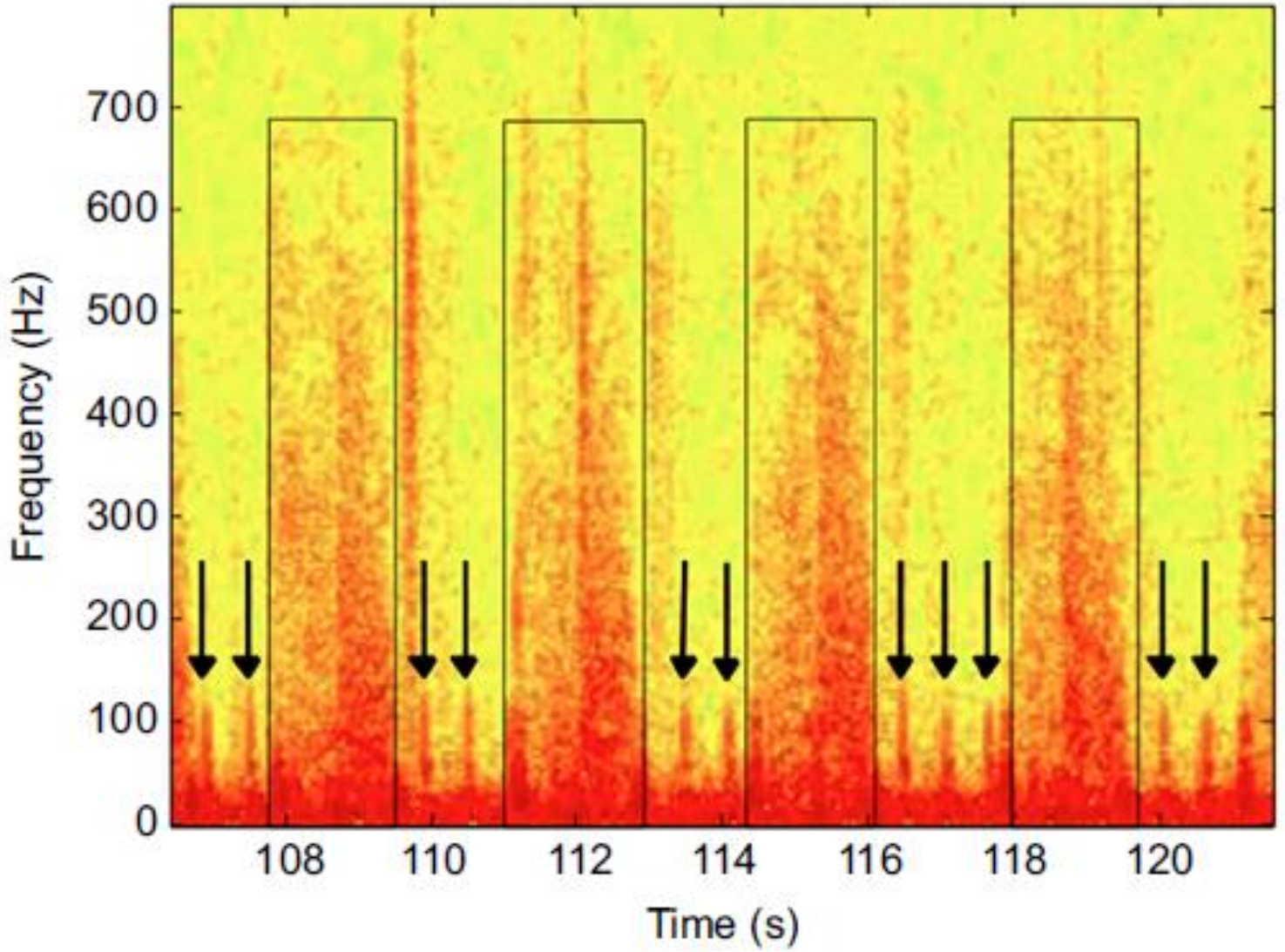
Evaluating the energy expenditure





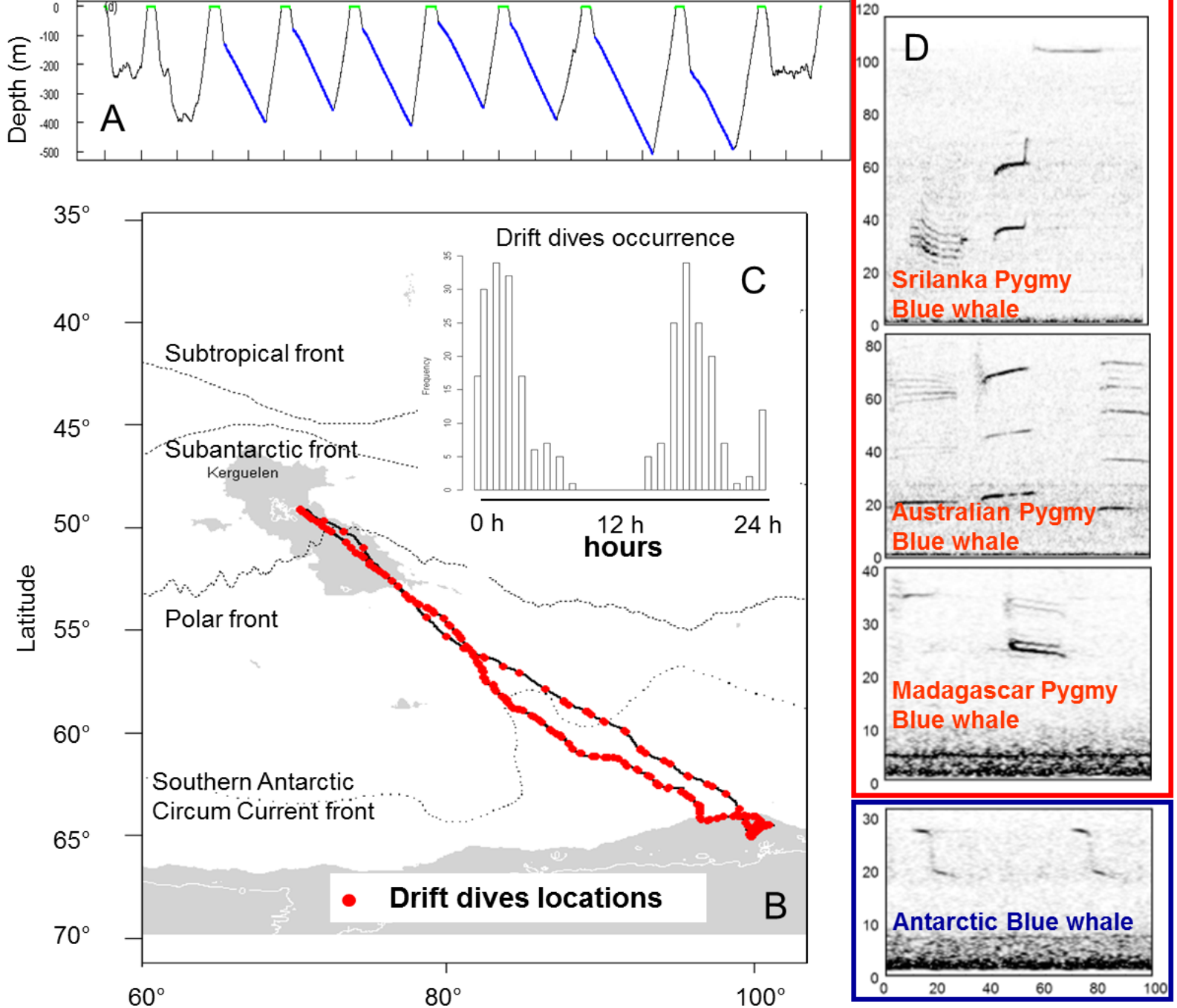






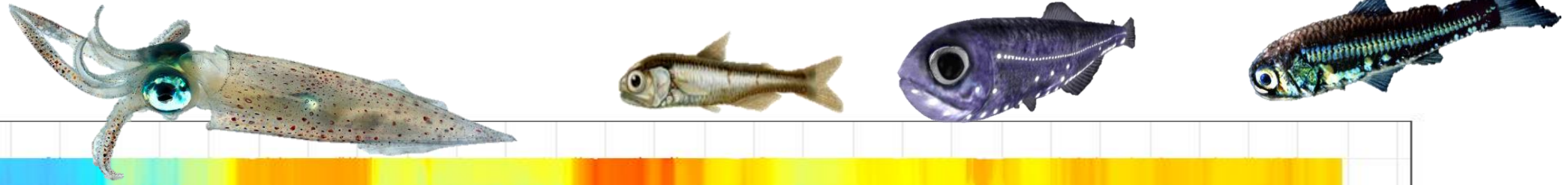
Genin A. Richard, G., Jouma'a J., Picard B., El Ksabi N., Vacquie Garcia J., Guinet, C. (2015). Marine Mammal Science.

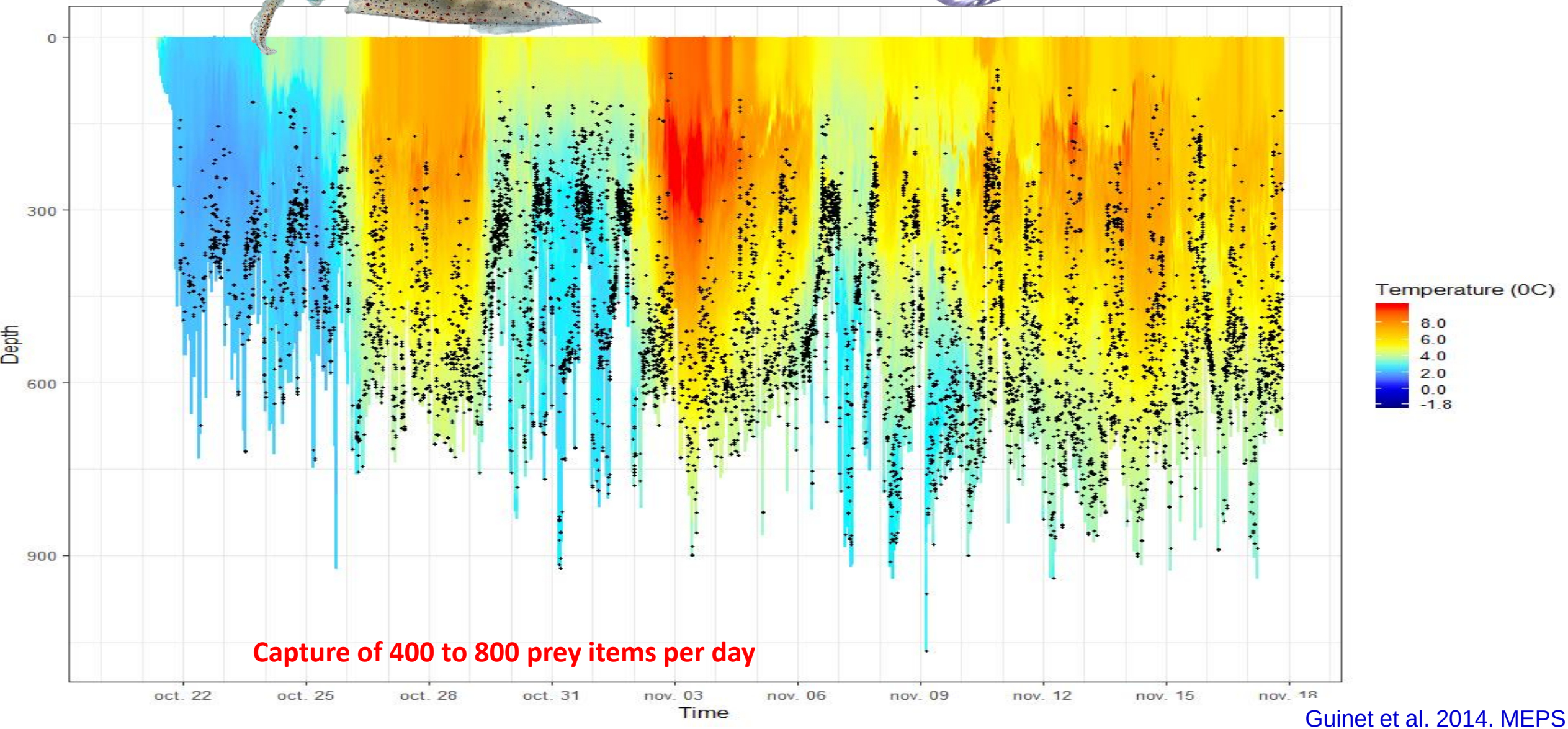
Day L., Jouma'a J., Bonnel J., Guinet C. (2017) Journal of Experimental Biology.


Depth (m)
0
-100
-200
-300
-400
-500
A
35°
40°
45°
50°
55°
60°
65°
70°
Latitude
Subtropical front
Subantarctic front
Kerguelen
Polar front
Southern Antarctic
Circum Current front
Drift dives occurrence
C
Frequency
0 h
12 h
24 h
hours
Drift dives locations
B
60°
80°
100°
Longitude
D
Srilanka Pygmy
Blue whale
Australian Pygmy
Blue whale
Madagascar Pygmy
Blue whale
Antarctic Blue whale


PHILLIP COLLA
OCEANLIGHT.COM

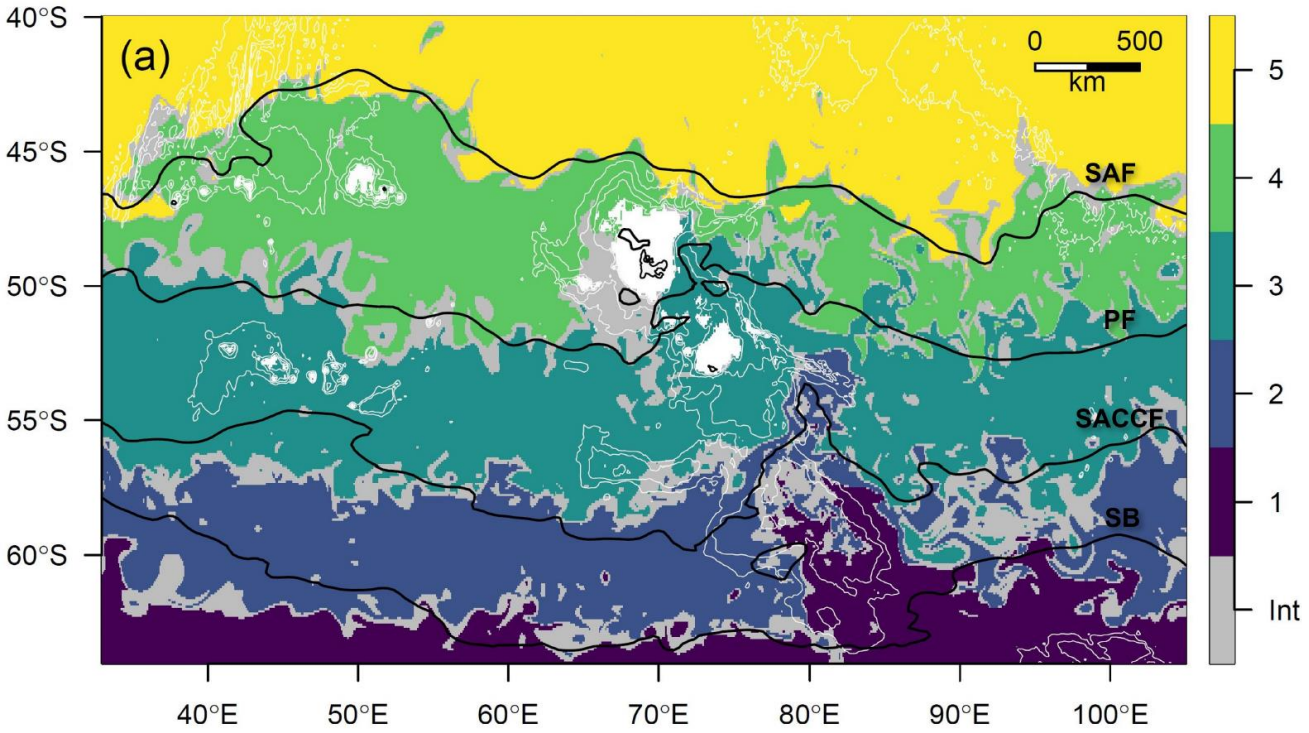
1) Tentatives de captures de proies

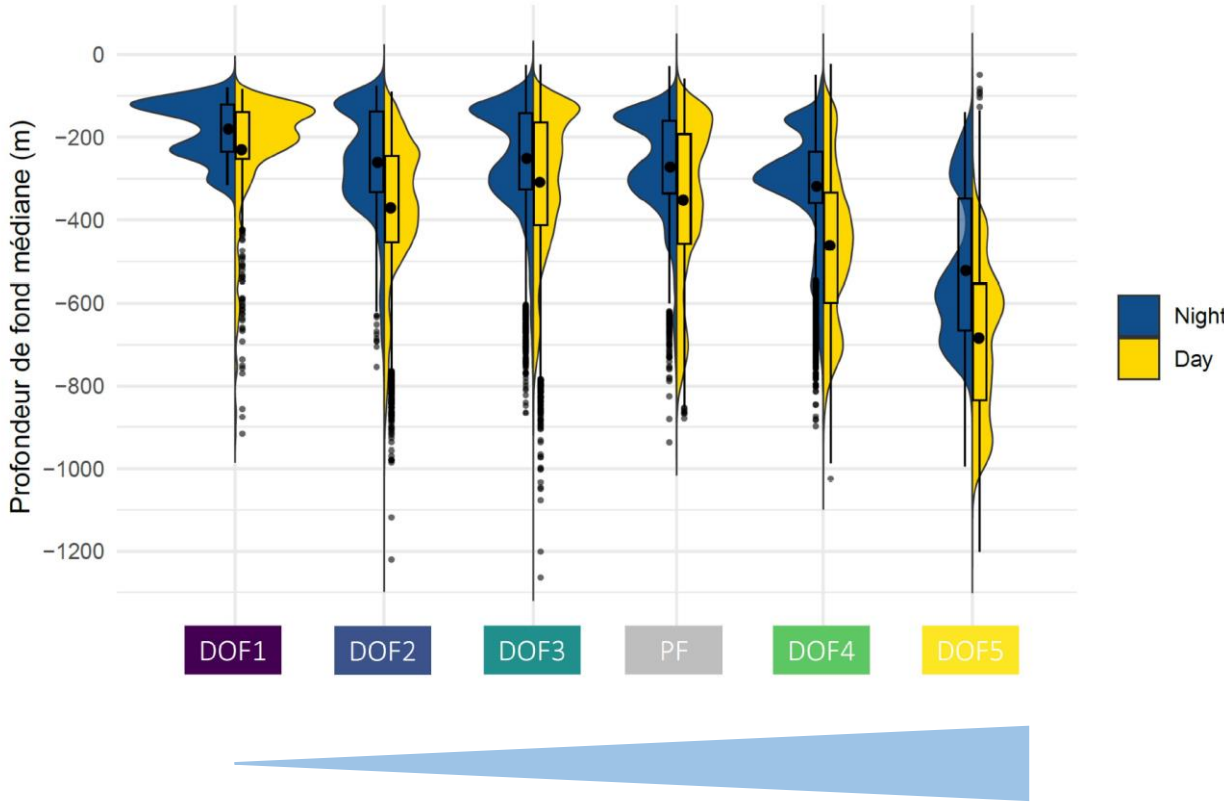




Capture of 400 to 800 prey items per day

Guinet et al. 2014. MEPS





Antarctique

Subtropicale

David Nerini

Nadège Fonvieille

Thèse Nadège Fonvielle D. Nerini & C. Guinet

Mediterranean Institute of Oceanography

Centre d'Études Biologiques de Chizé

Institut Pythéas Observatoire des Sciences de l'Univers Aix*Marseille Université

Aix*Marseille université

Chaque année 15 femelles éléphants de mer équipés de balises :

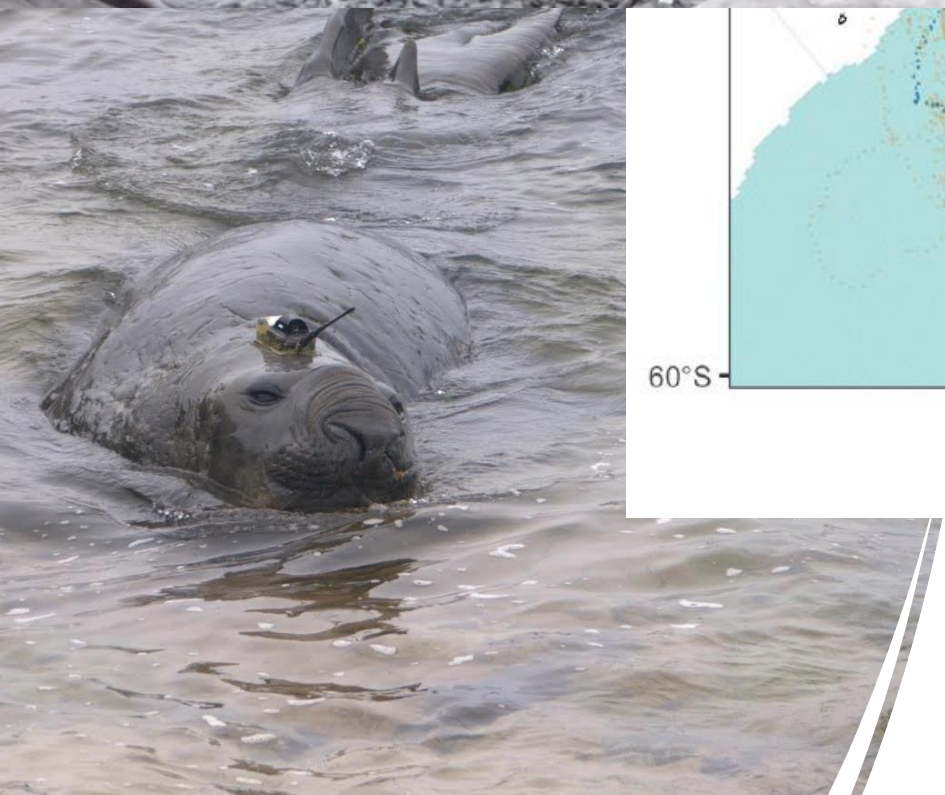
Effectuent 153 000 plongées

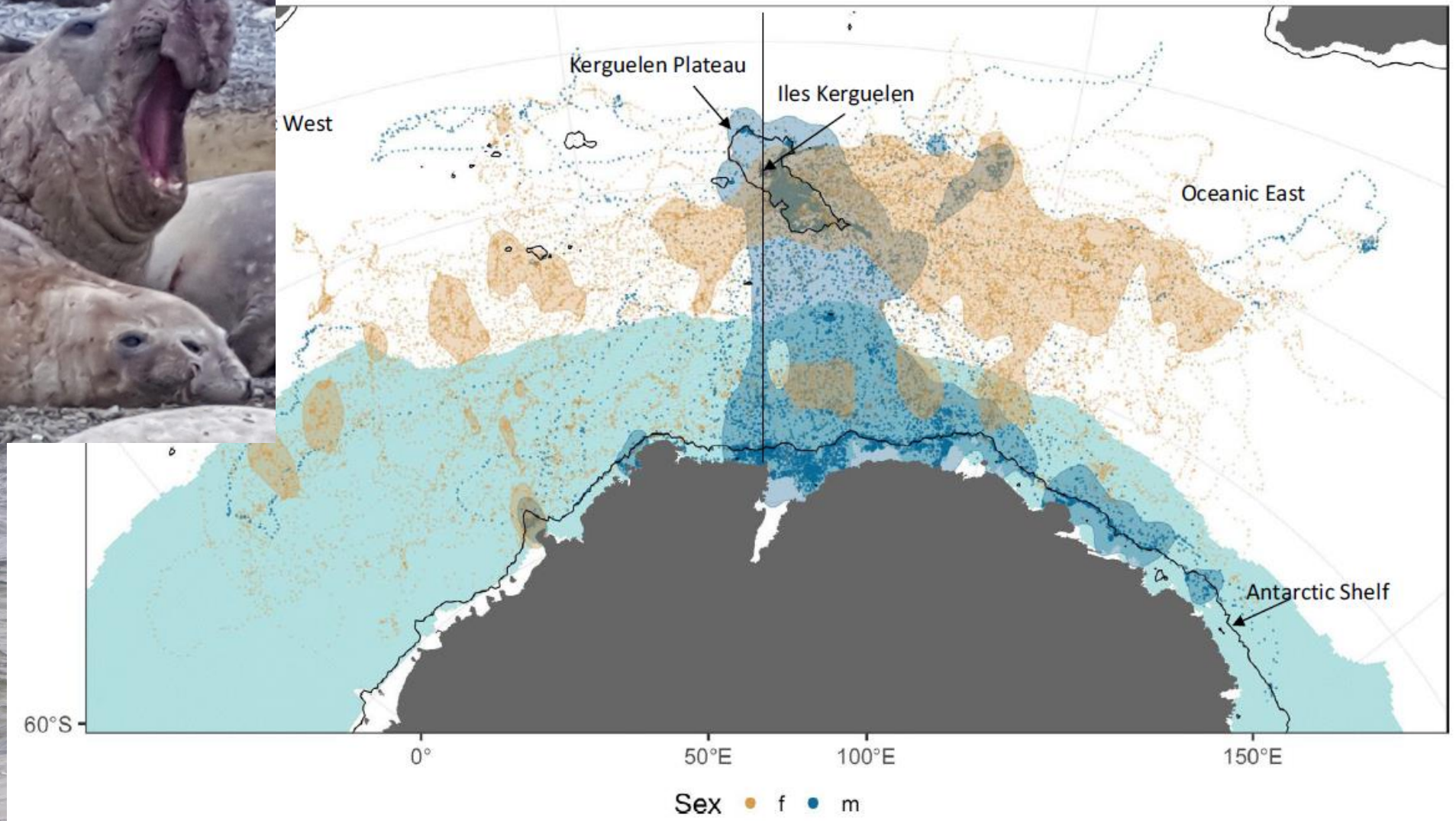
Couvrent 6.2 millions km² de l'océan austral

Échantillonnent 4.7 million km³ de l'océan Austral

Consoment 3.3 million de poissons

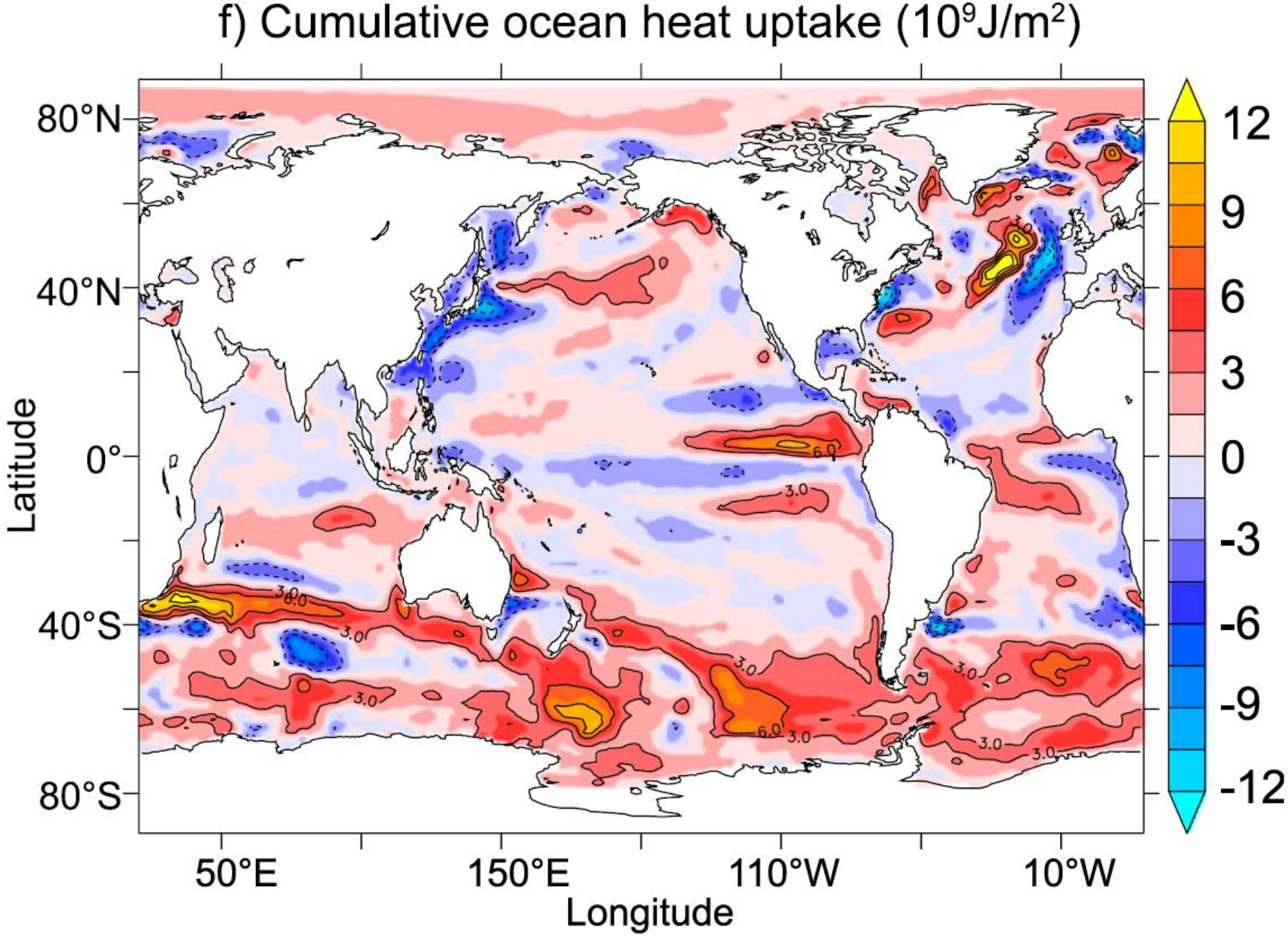
Permettent d'identifier les habitats écologiquement importants



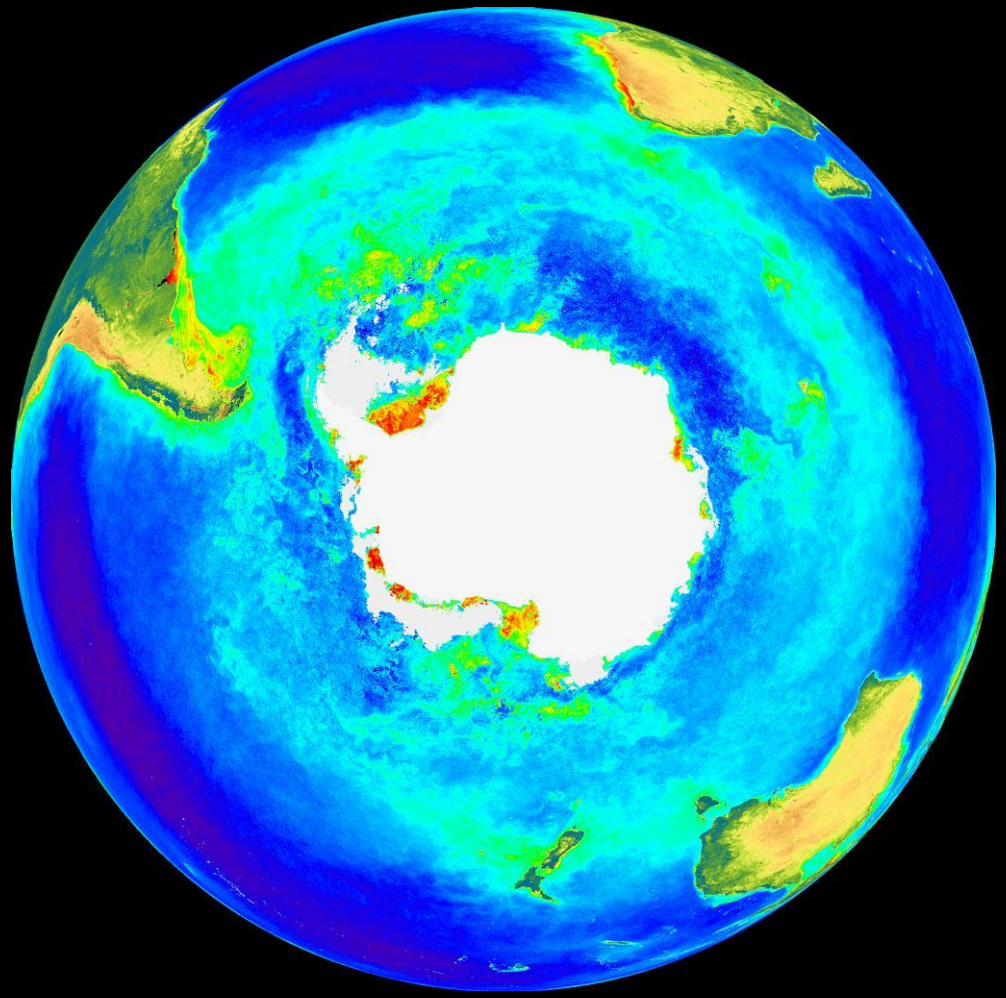


Bailleul, F., et al. (2007). "Southern elephant seals from Kerguelen Islands confronted by Antarctic Sea ice. Changes in movements and in diving behaviour." Deep-Sea Research Part Ii-Topical Studies in Oceanography 54(3-4): 343-355.

Hindell, M. A., et al. (2021). "Inter- and intra sex habitat partitioning in the highly dimorphic southern elephant seal." Ecology and Evolution.


f) Cumulative ocean heat uptake (10^9J/m^2)
80°N
40°N
0°
40°S
80°S
Latitude
50°E
150°E
110°W
10°W
Longitude
12
9
6
3
0
-3
-6
-9
-12
6.0
3.0

Comment la composante biologique de l'océan Austral réagit-elle à ce réchauffement

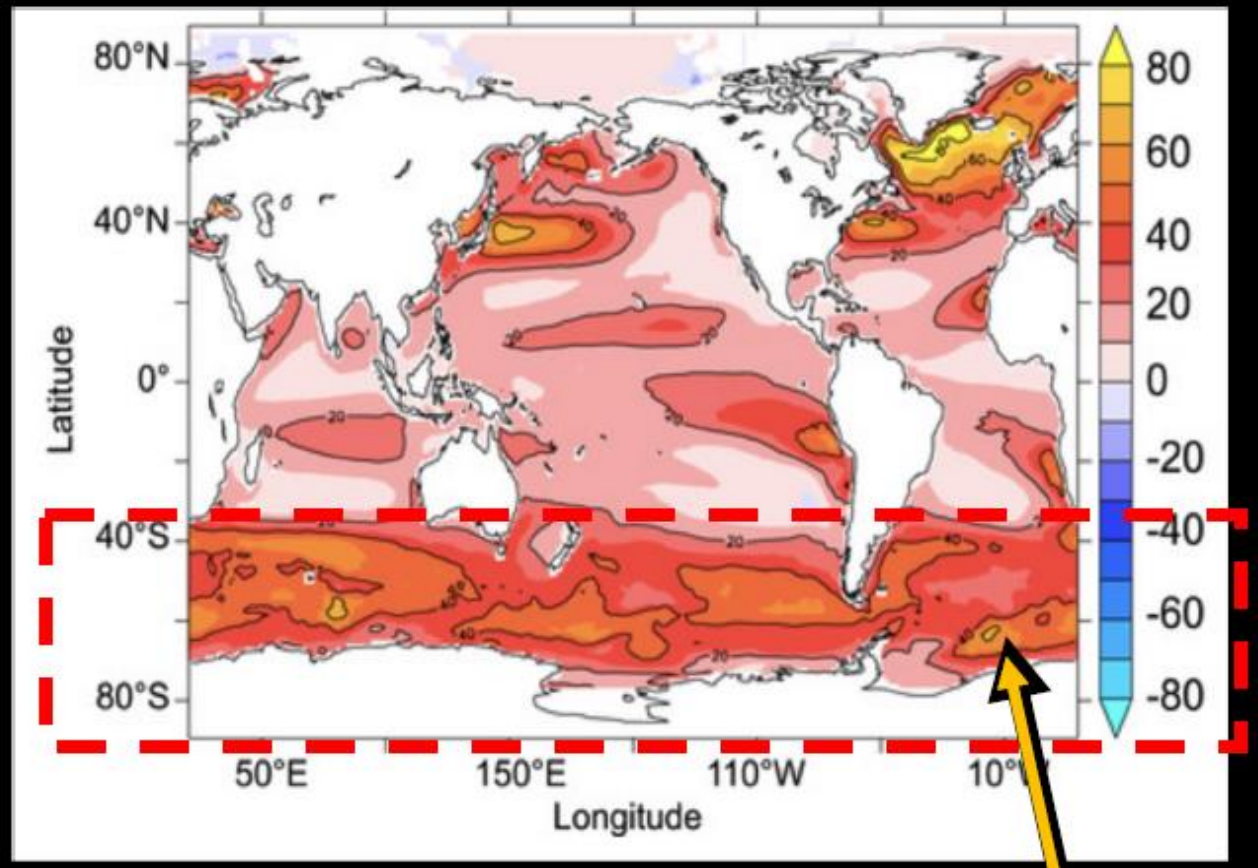


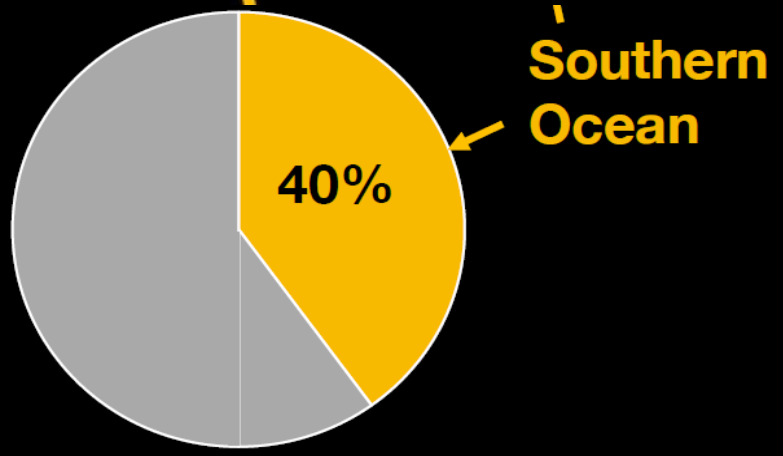
Une augmentation de la biomasse de phytoplancton[1]

Une modification de la compositon des communautés de phytoplancton[2]

[1]Del Castillo et al. 2019, GRL

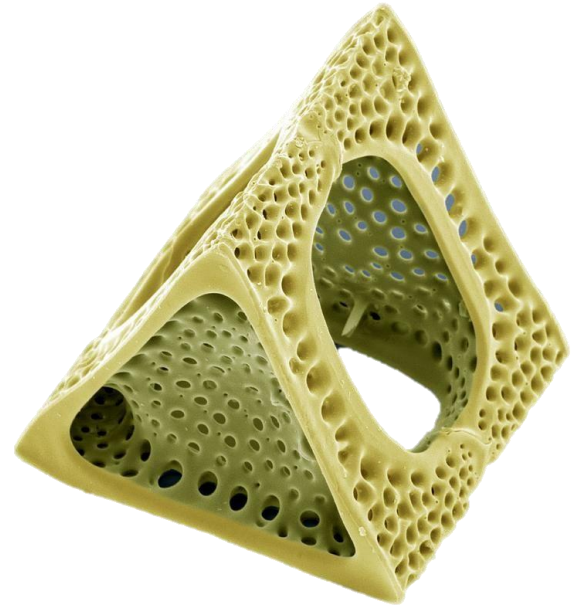
[2]Mestre et al. 2020. PRSL

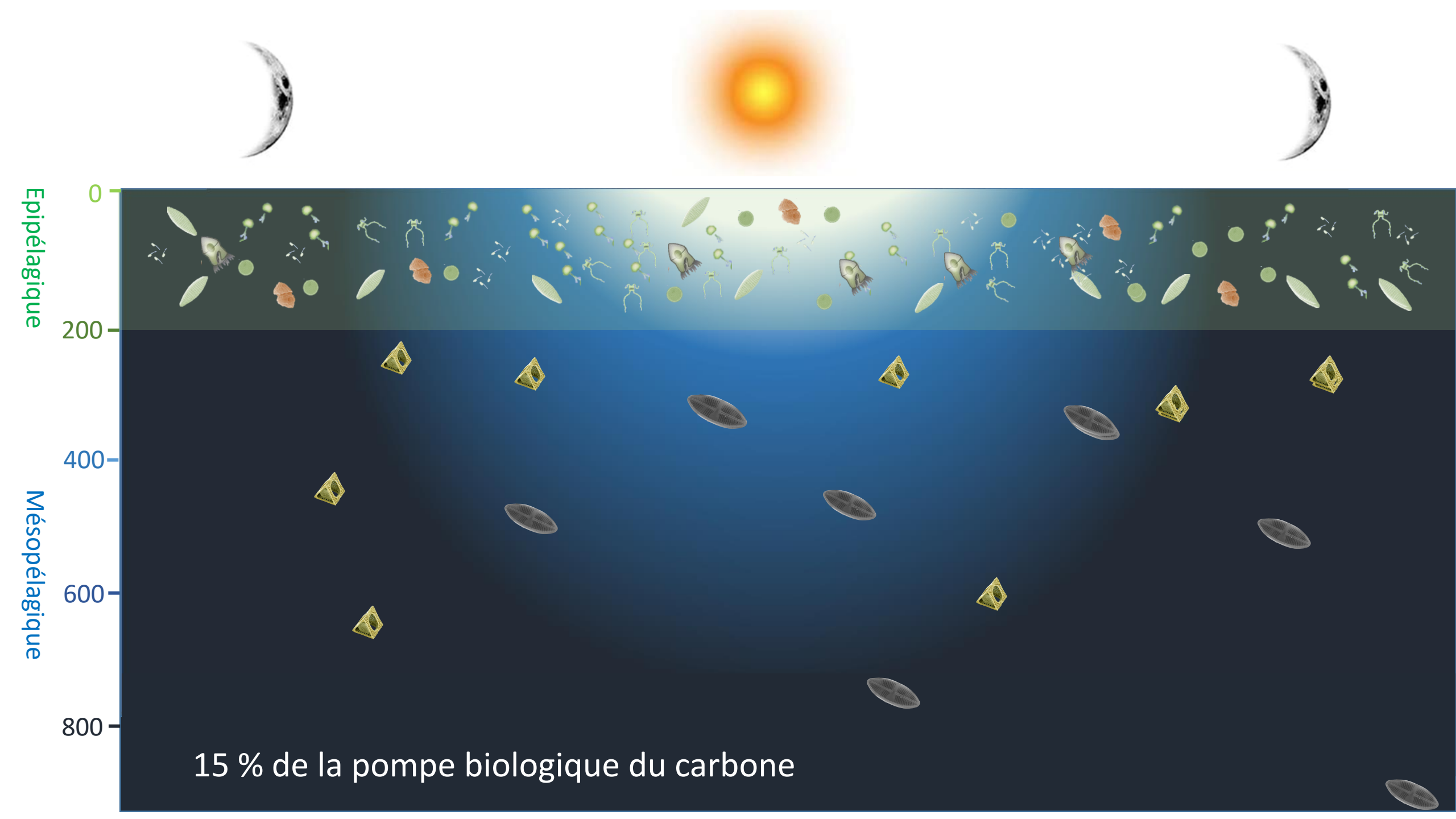


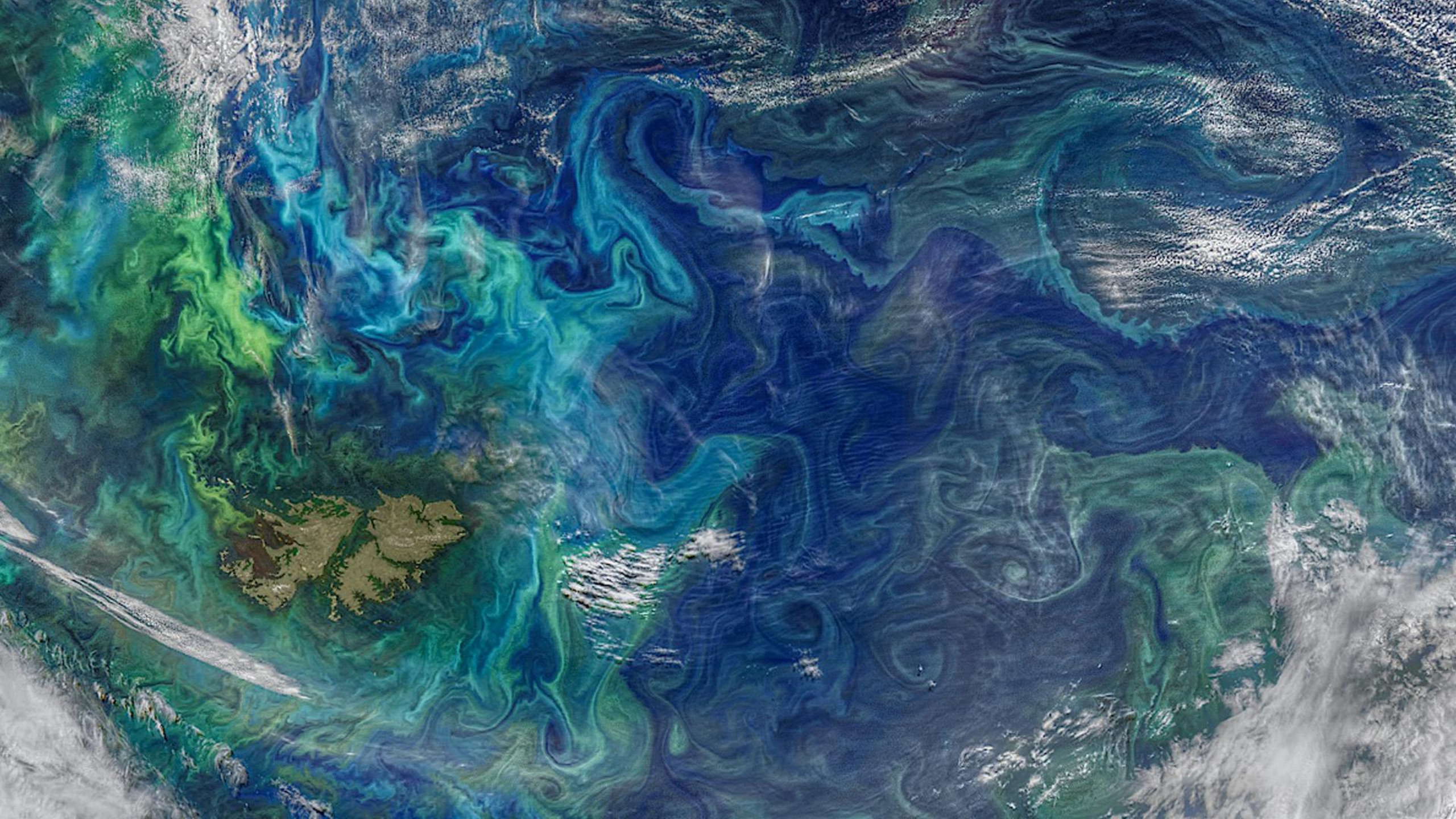


Frölicher et al., 2015

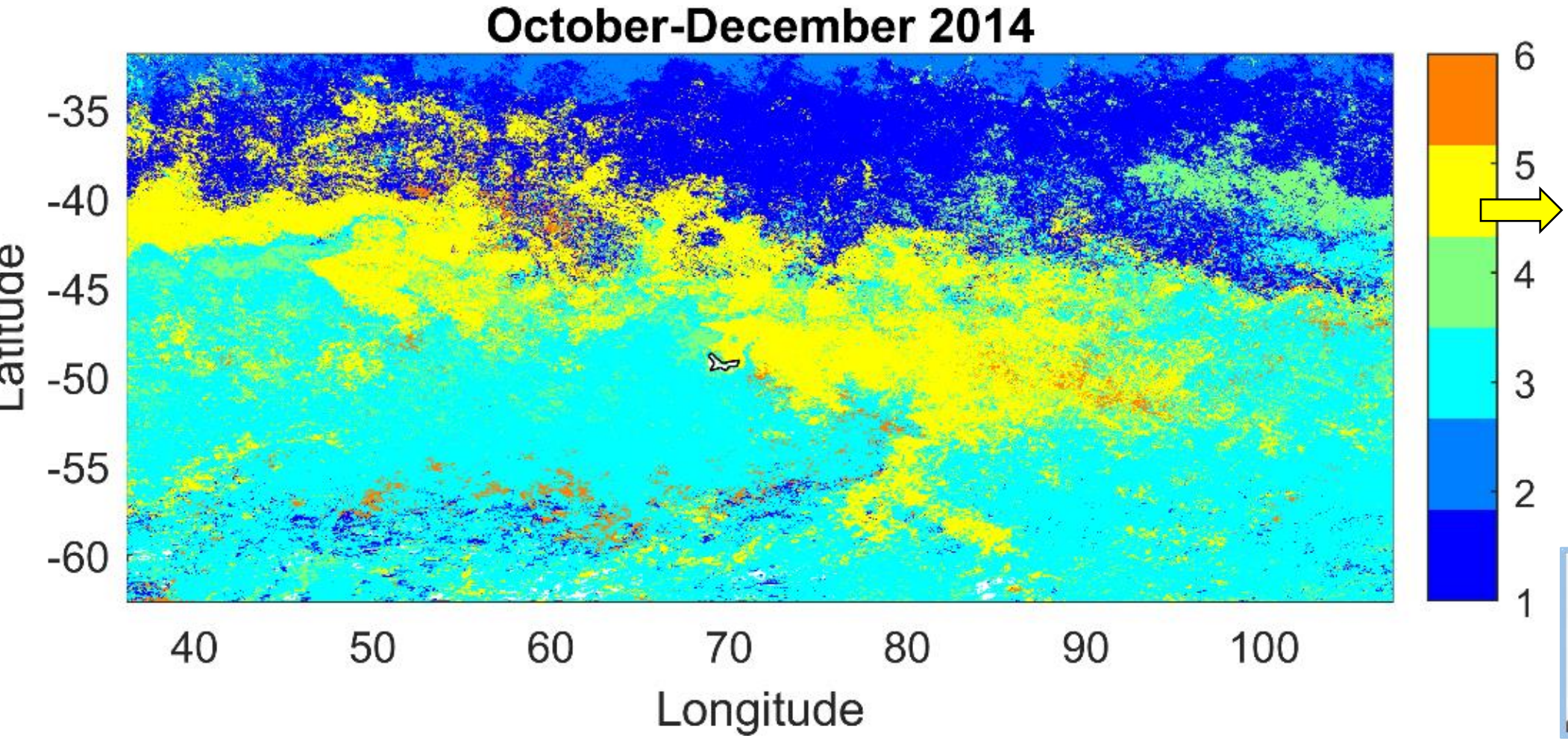
La pompe biologique représenterait jusqu'à 30% de ces 40 %



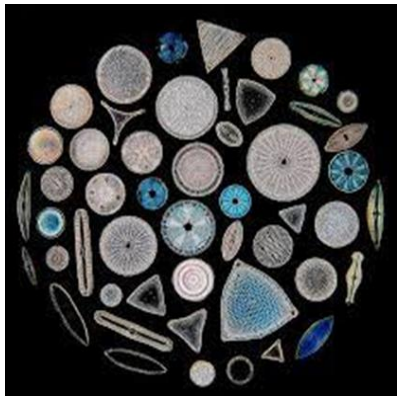

Epipélagique
Mésopélagique
0
200
400
600
800
15 % de la pompe biologique du carbone



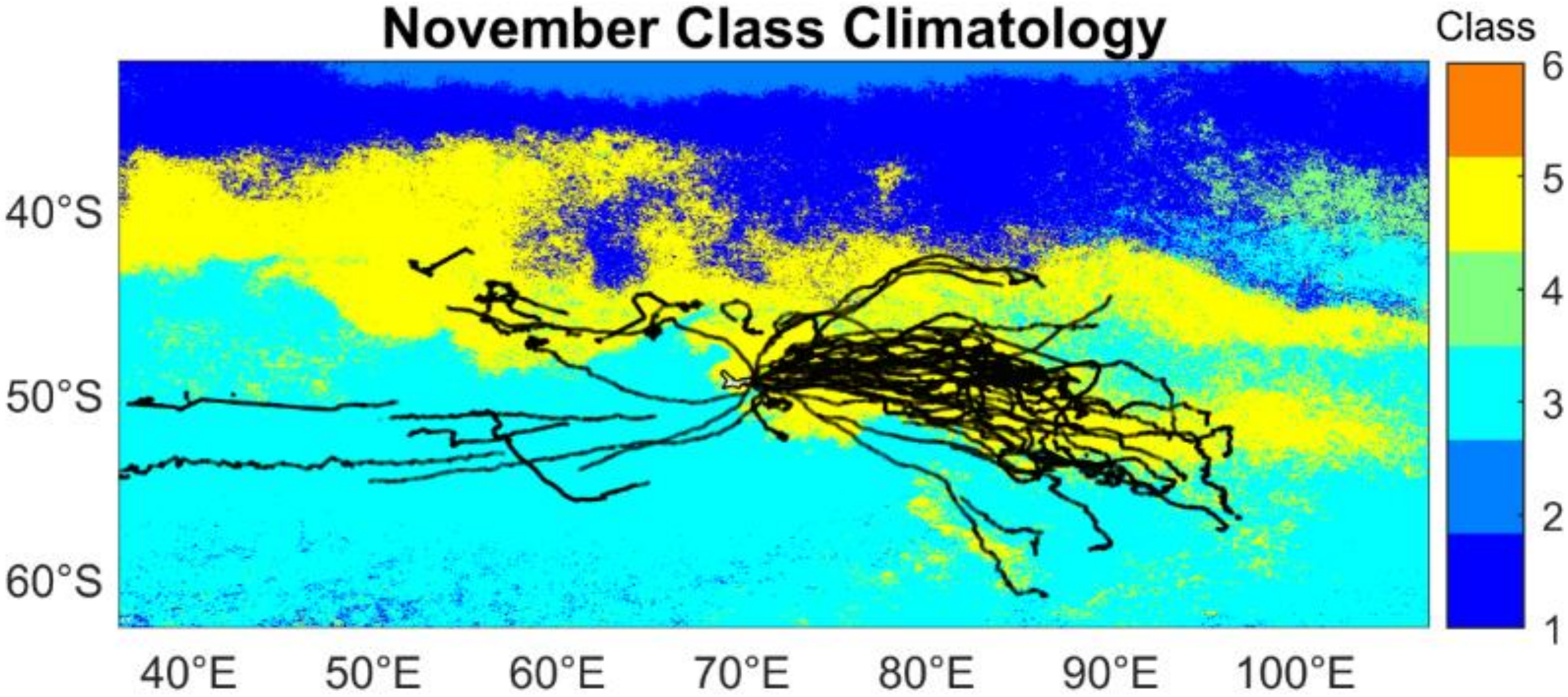
A partir des différences de couleurs 6 grandes communautés de phytoplancton ont été identifiées dans l'Océan Austral.



Diatomées



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


November Class Climatology
Class
6
5
4
3
2
1
40°S
50°S
60°S
40°E
50°E
60°E
70°E
80°E
90°E
100°E

Phytoplancton

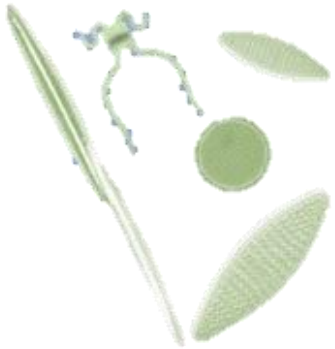
Niveaux Trophiques Intermédiaires

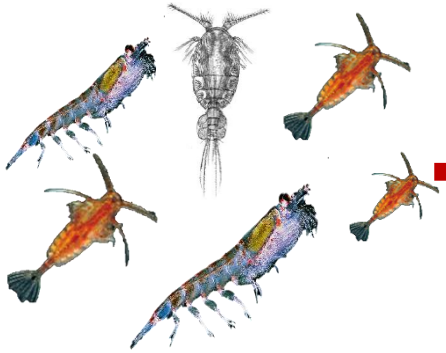
Zooplancton

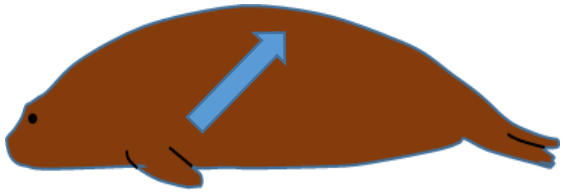
Micronecton

Prédateurs supérieurs (sentinelles)

Diatomées (Grande taille Forte Valeur nutritionnelle)

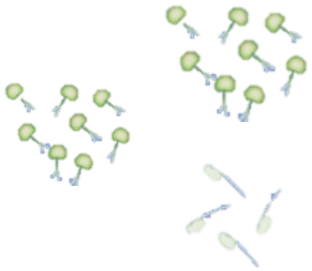


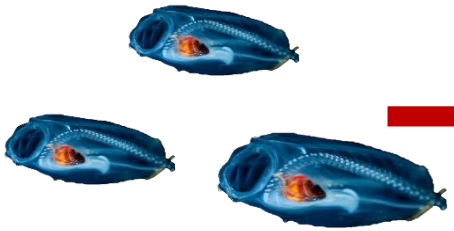




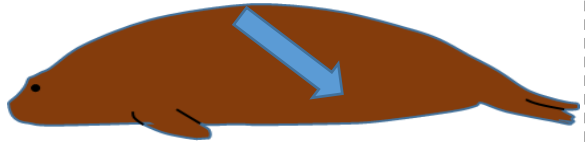
Performances de pêche

Pico-nano-phytoplancton (petite taille, Faible valeur nutritionnelle)

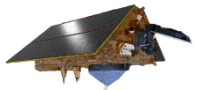




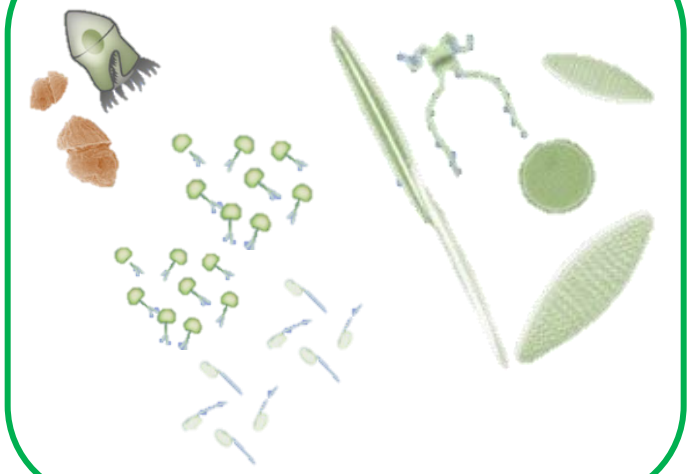
?



De nouveaux biologgers afin de mieux comprendre l'écologie des prédateurs marins et la biologie de l'Océan ?

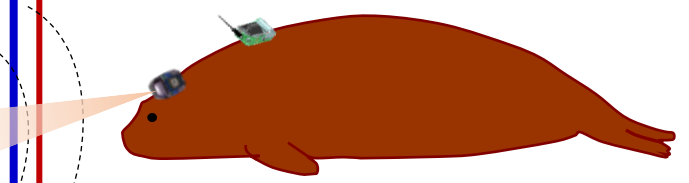


Phytoplankton

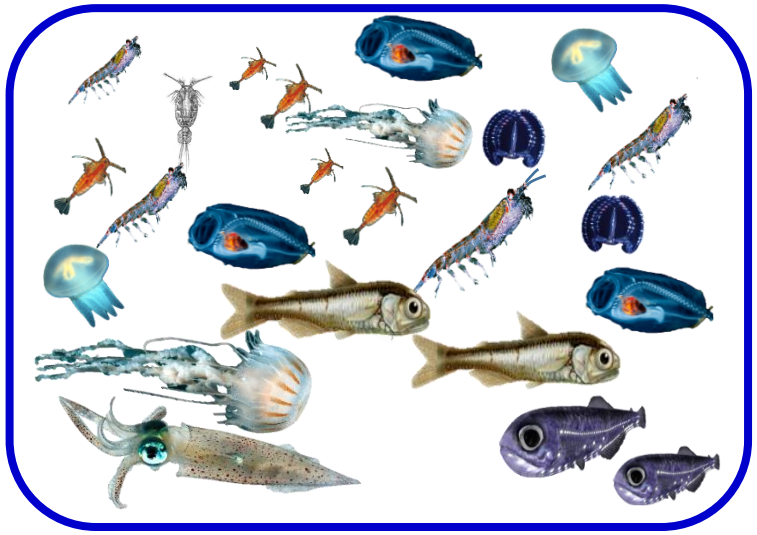


Des niveaux trophiques intermédiares méconus

Etudier l'écologie des prédateurs marins (succès de pêche, comportement…)



ANR SOTroC (en cours d'évaluation)

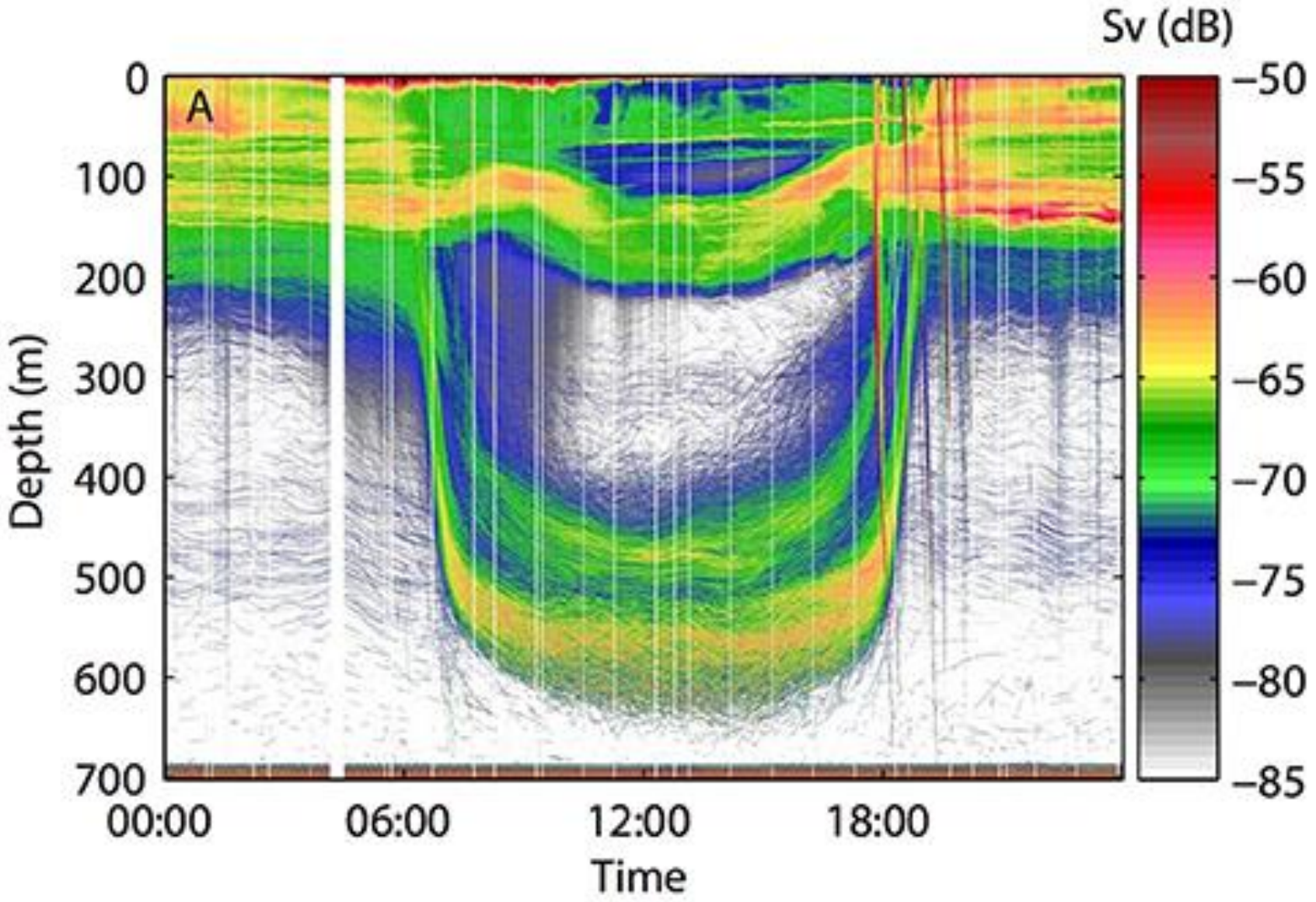


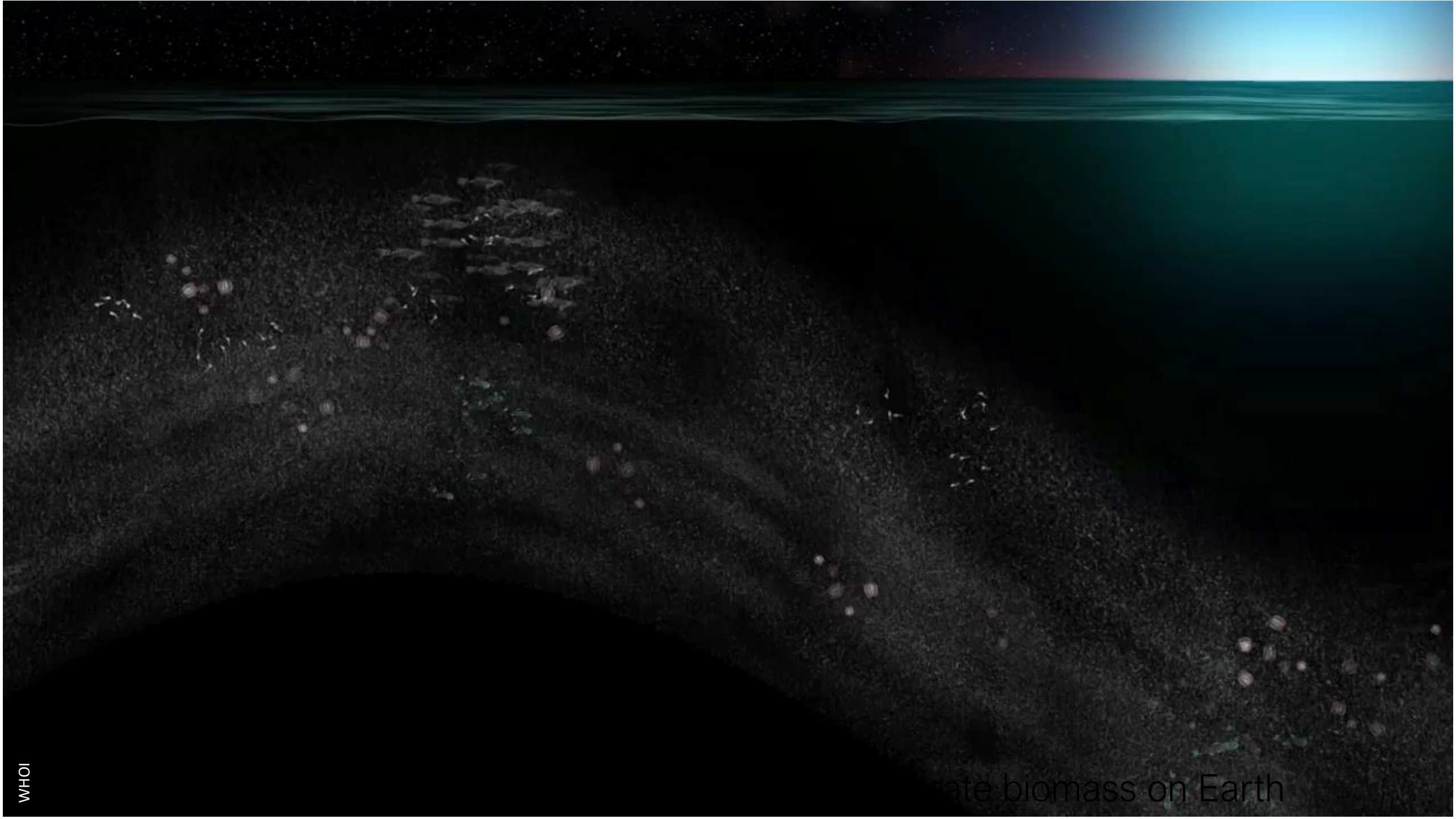
Des niveaux trophiques intermédiares méconus

La plus forte biomasse animale sur notre planète
Entre 10 et 16 Milliards de Tonnes

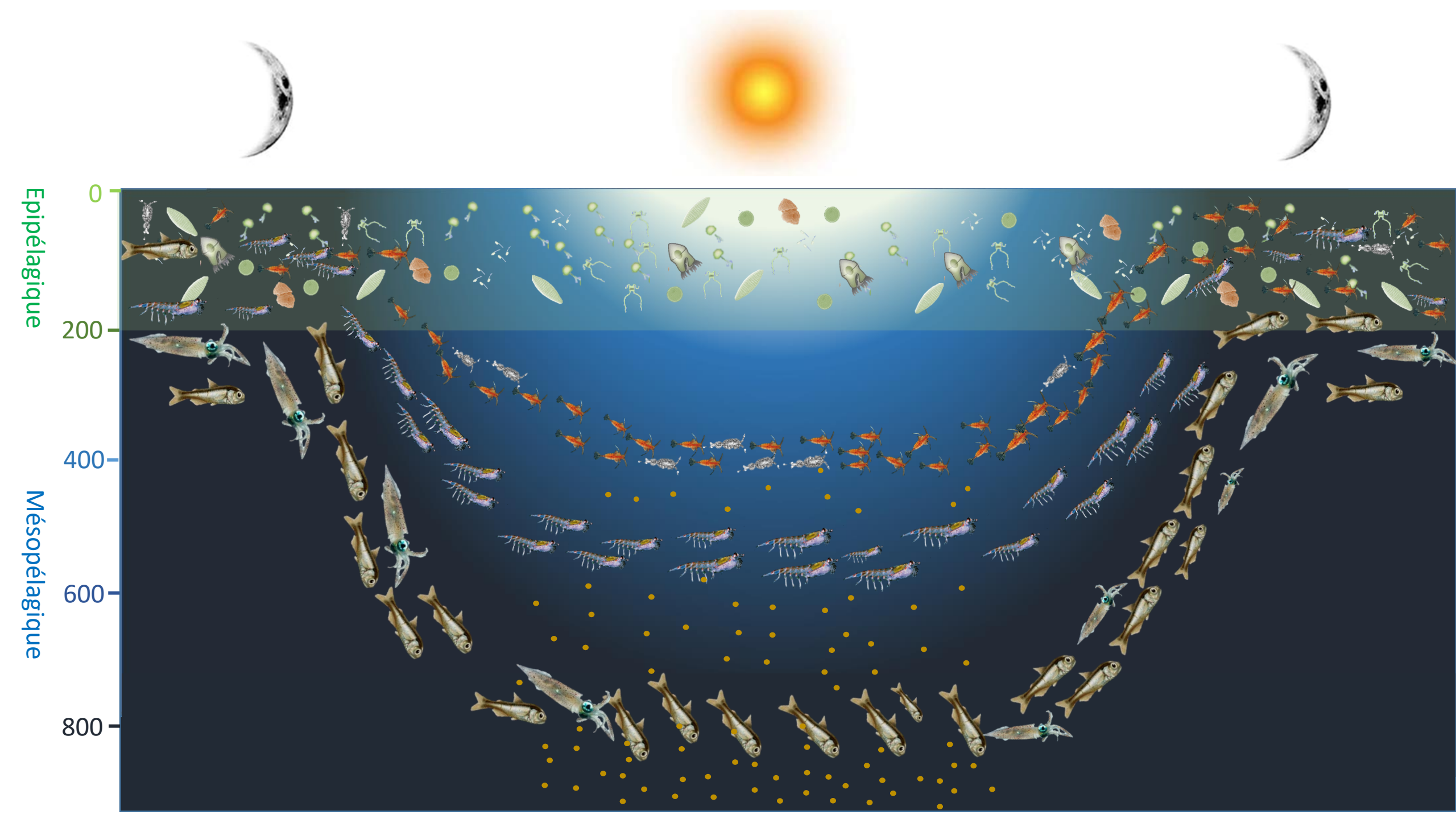
La plus importante migration quotidienne sur terre

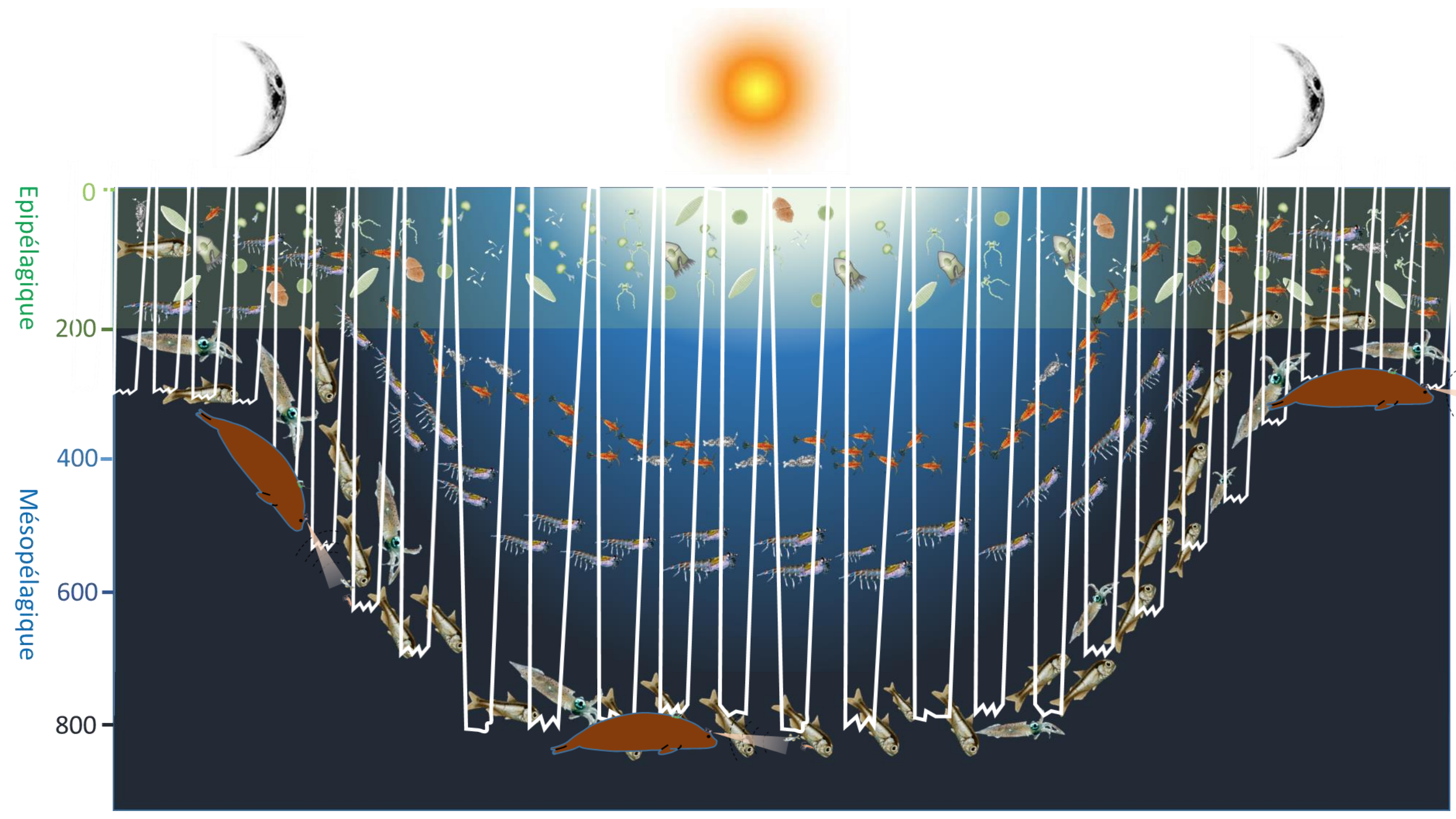
Représente une contribution significative à la pompe biologique du CO_2





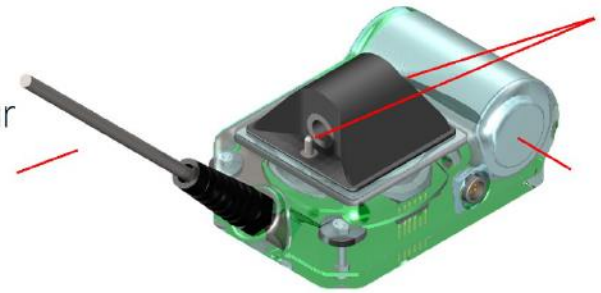
ate biomass on Earth

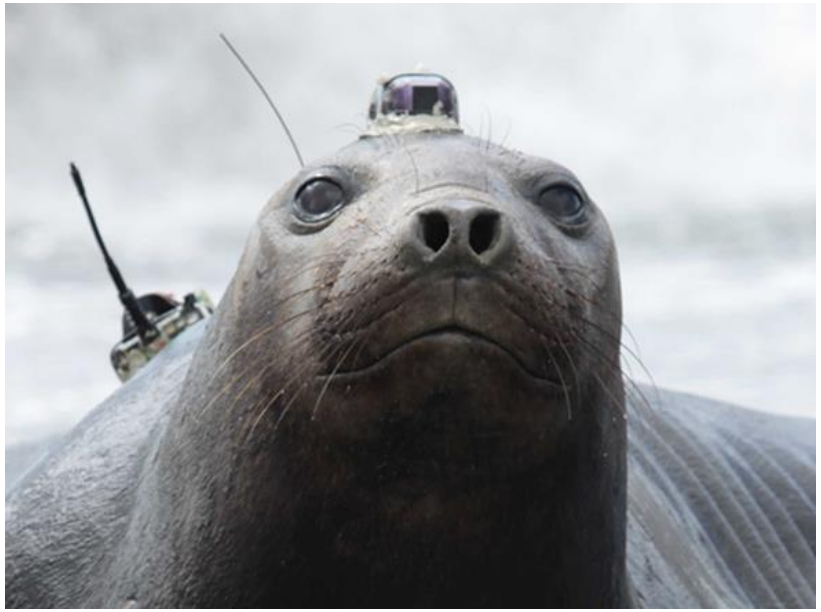

Epipélagique
Mésopélagique
0
200
400
600
800


Epipélagique
Mésopélagique
0
200
400
600
800

CTD-SRDL

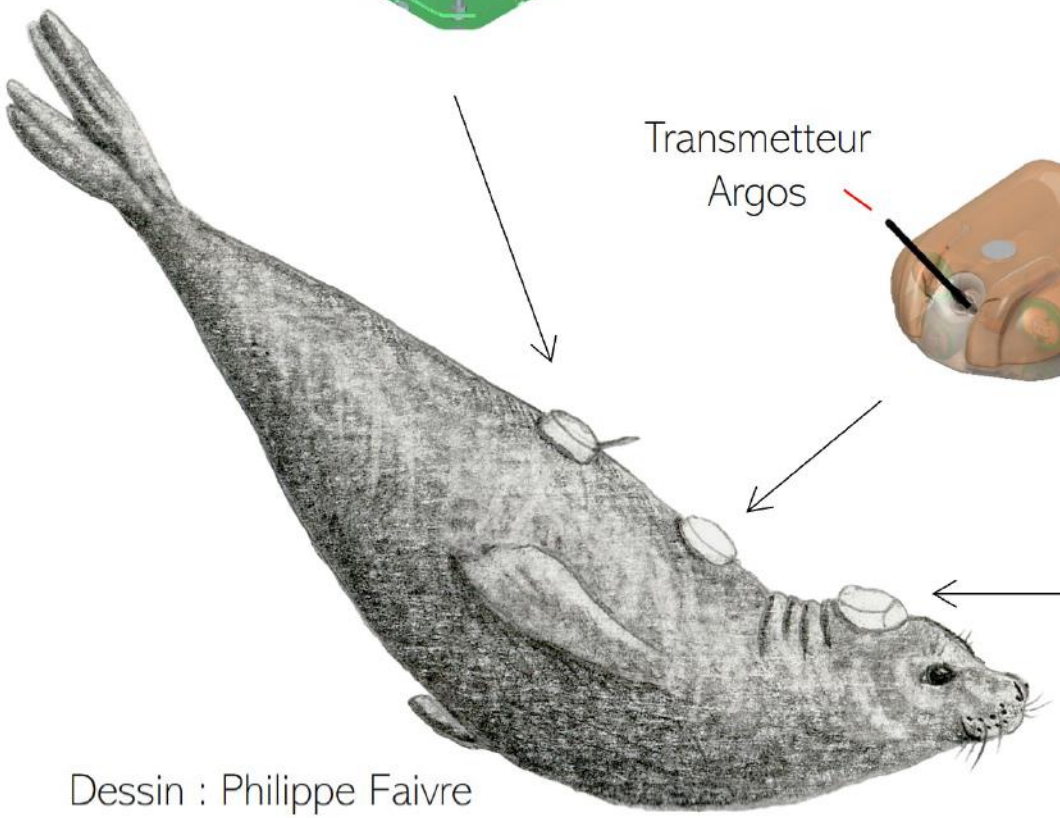
105 x 70 x 40 mm
545 g





SPOT-293

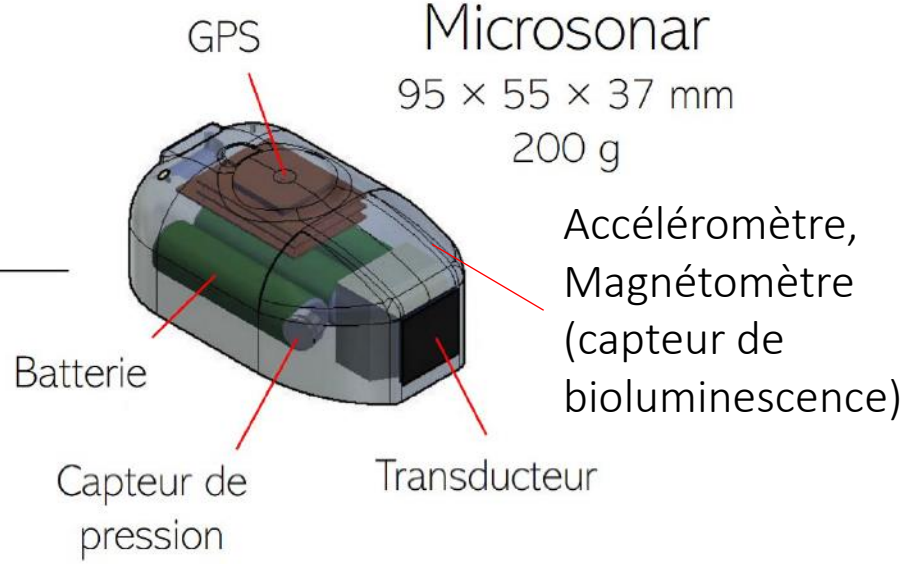
72 x 56 x 24 mm
119 g



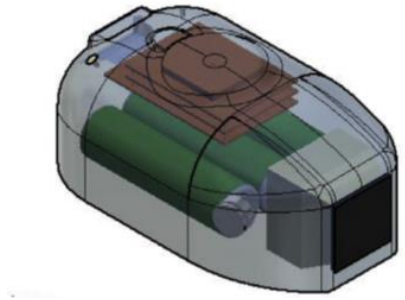
Dessin : Philippe Faivre

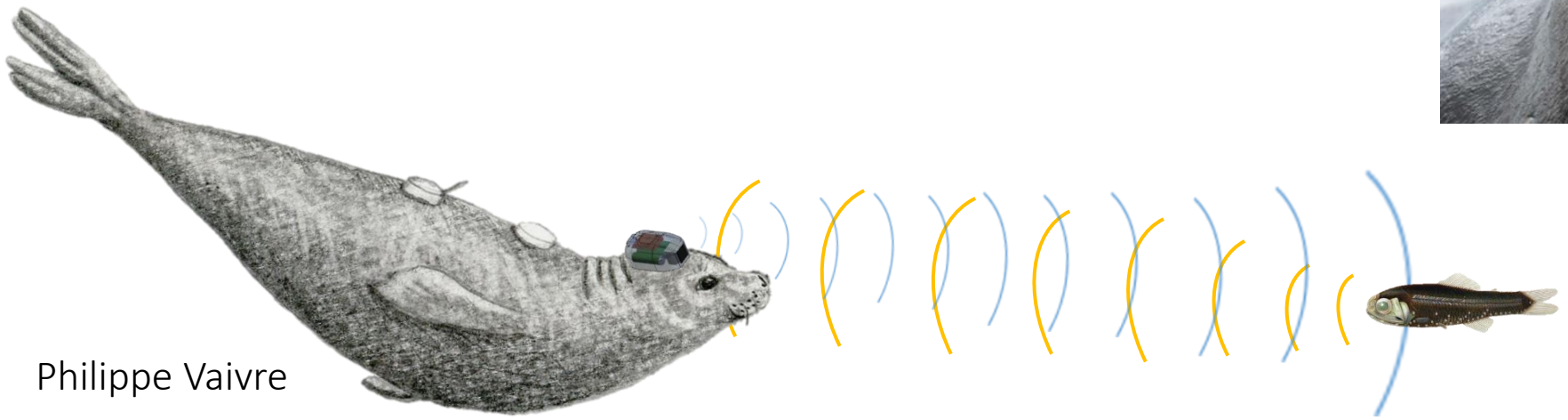
Microsonar

95 × 55 × 37 mm
200 g



Accéléromètre,
Magnétomètre
(capteur de
bioluminescence)

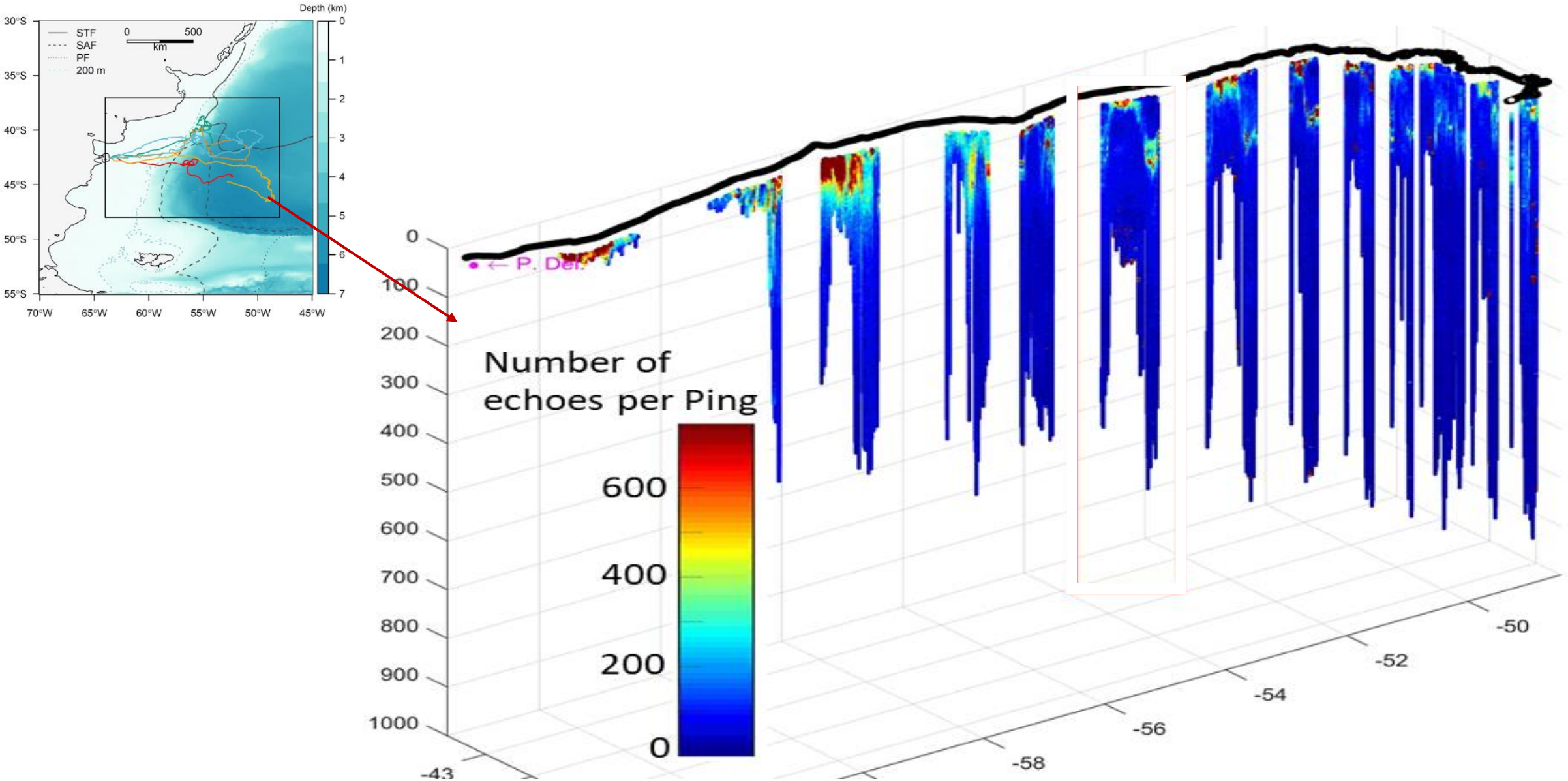




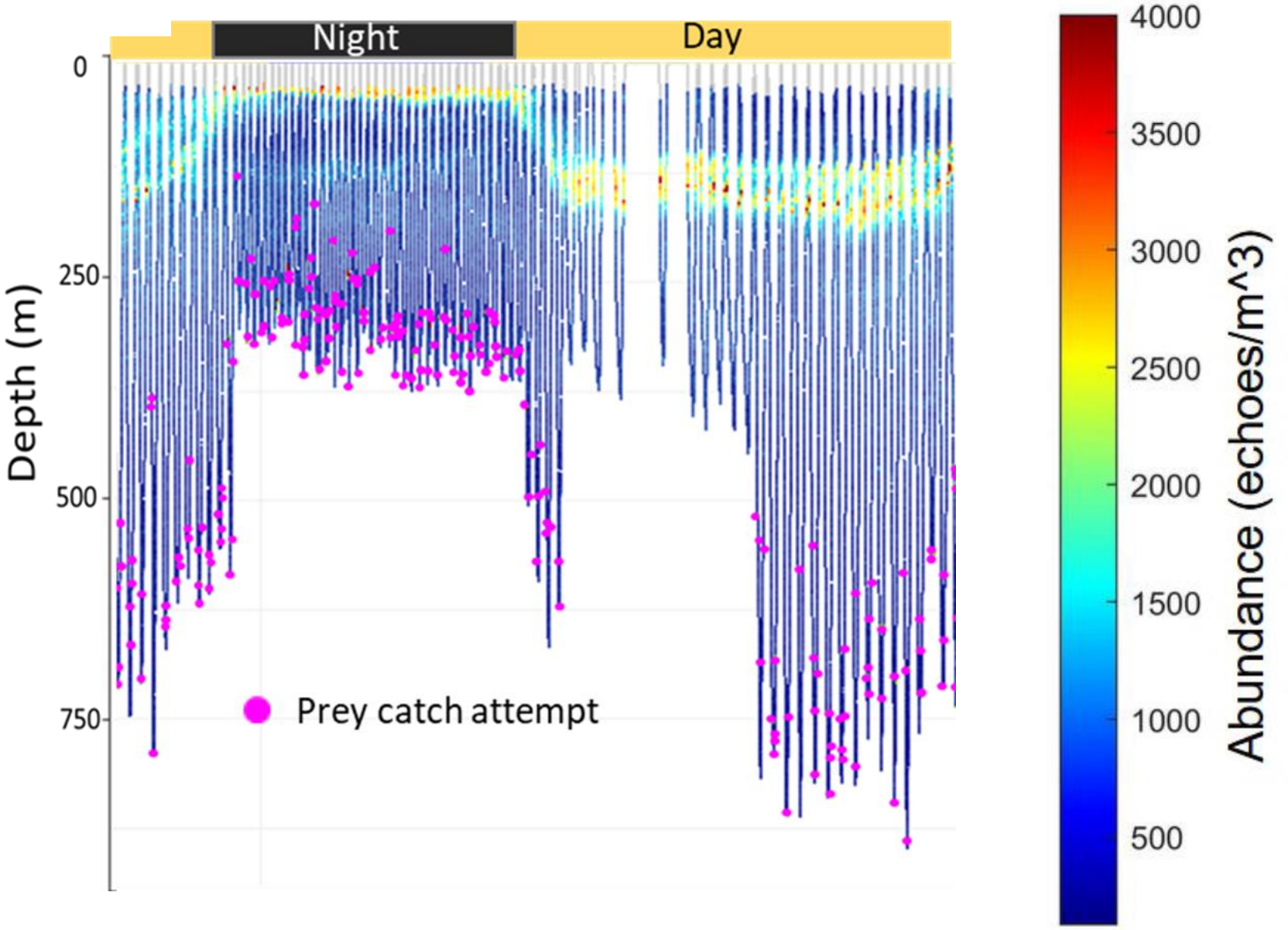
Philippe Vaivre

Des informations quantitatives sur les échos générés

Taille acoustique (>2 mm-quelque dizaine de cm)
L’intensité acoustique
Abondance
Comportement

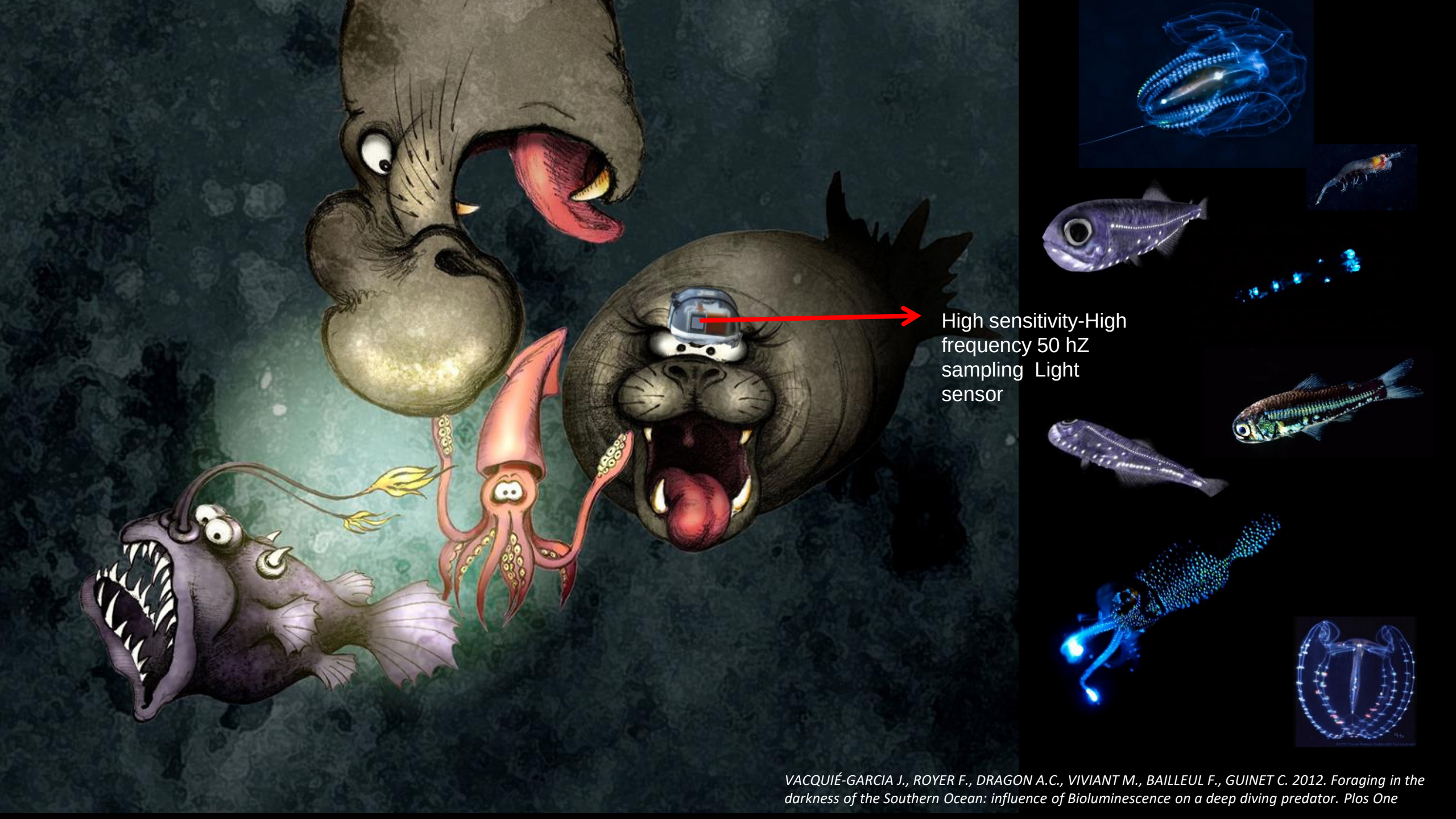


Coll. University of Buenos Aires, CIMA-CONICET, Argentina; M. Saraceno, D. Sciamarella.

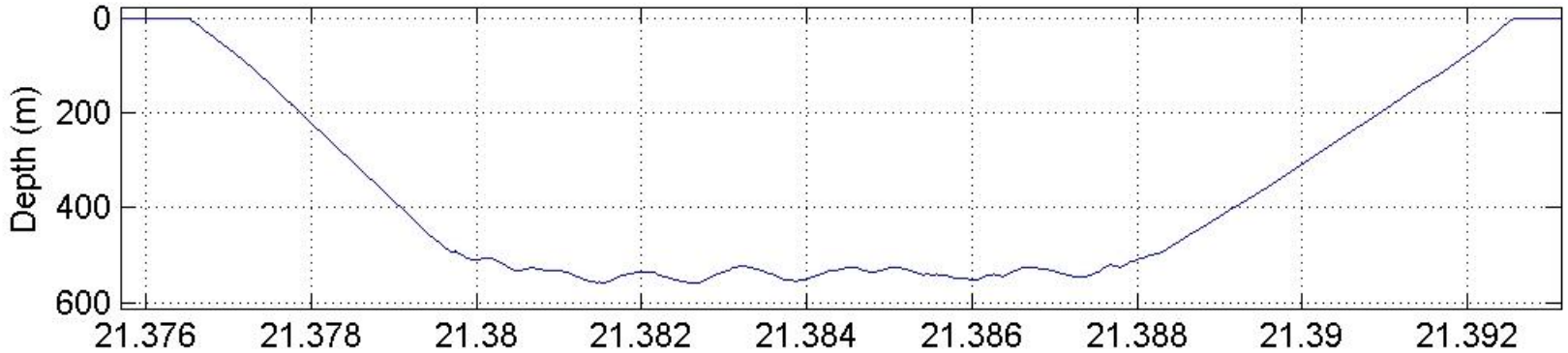


Tournier M, Goulet P, Johnson M, Nerini D, Fonvieille N, Guinet C (2021). A novel animal-borne miniature echosounder to observe the distribution and migration patterns of intermediate trophic levels in the Southern Ocean. Journal of Marine System, 223: 103608. https://doi.org/10.1016/j.jmarsys.2021.103608

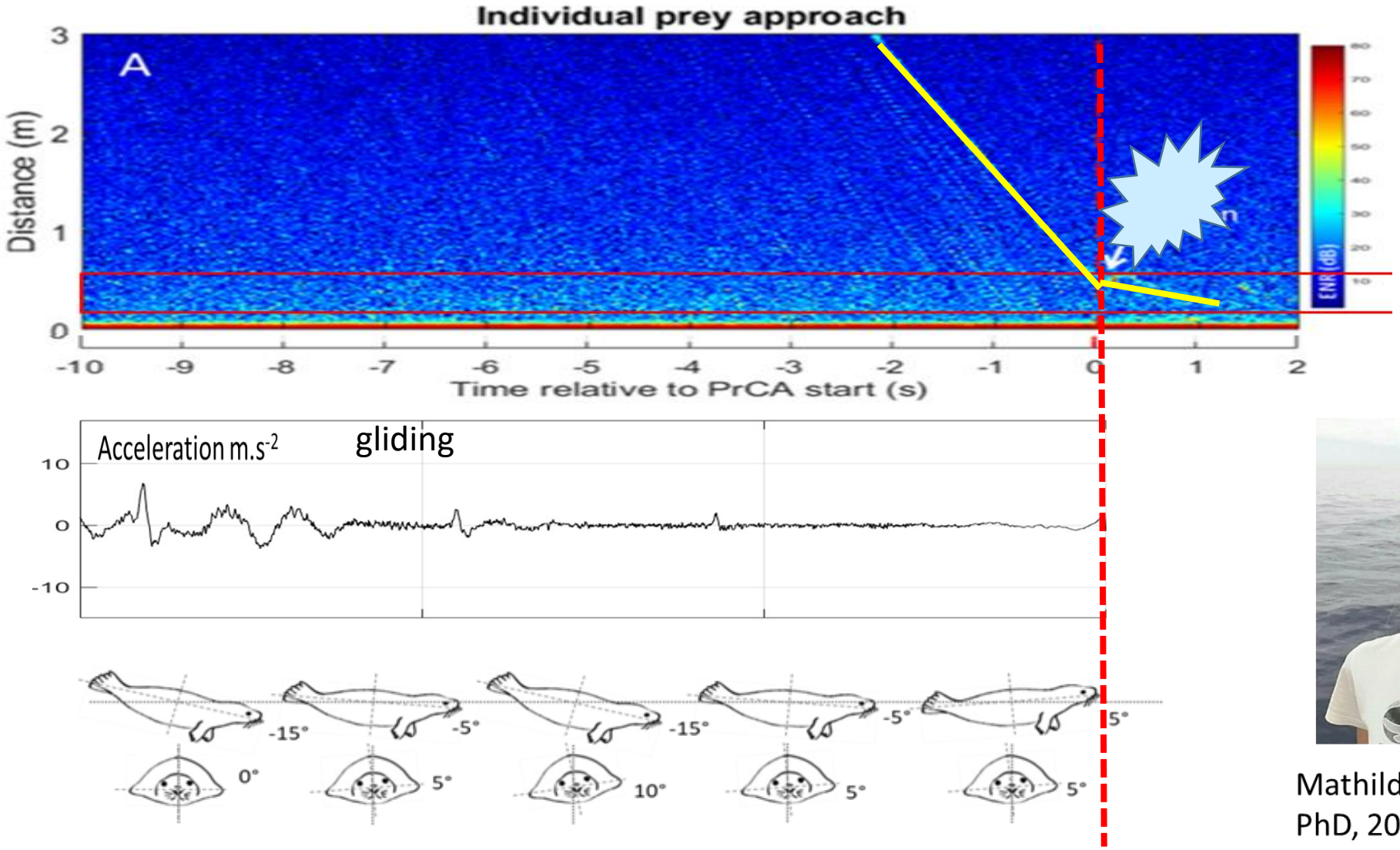
micro-echosonder et capteur de bioluminescence couple à une balise océanographique



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

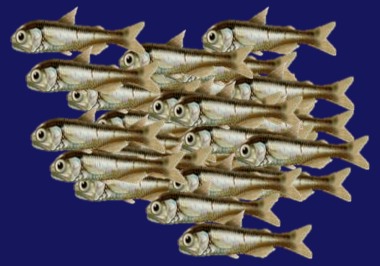

Depth (m)
0
200
400
600
21.376
21.378
21.38
21.382
21.384
21.386
21.388
21.39
21.392

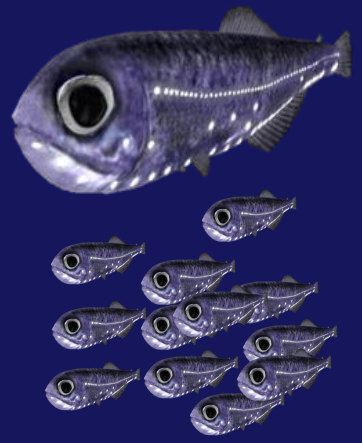
Investigating the foraging behaviour

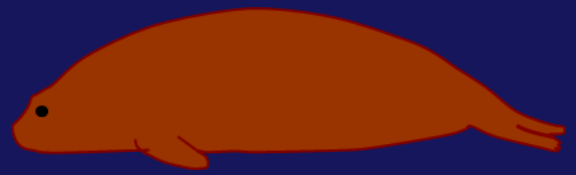


Mathilde Chevallay, PhD, 2021, CEBC

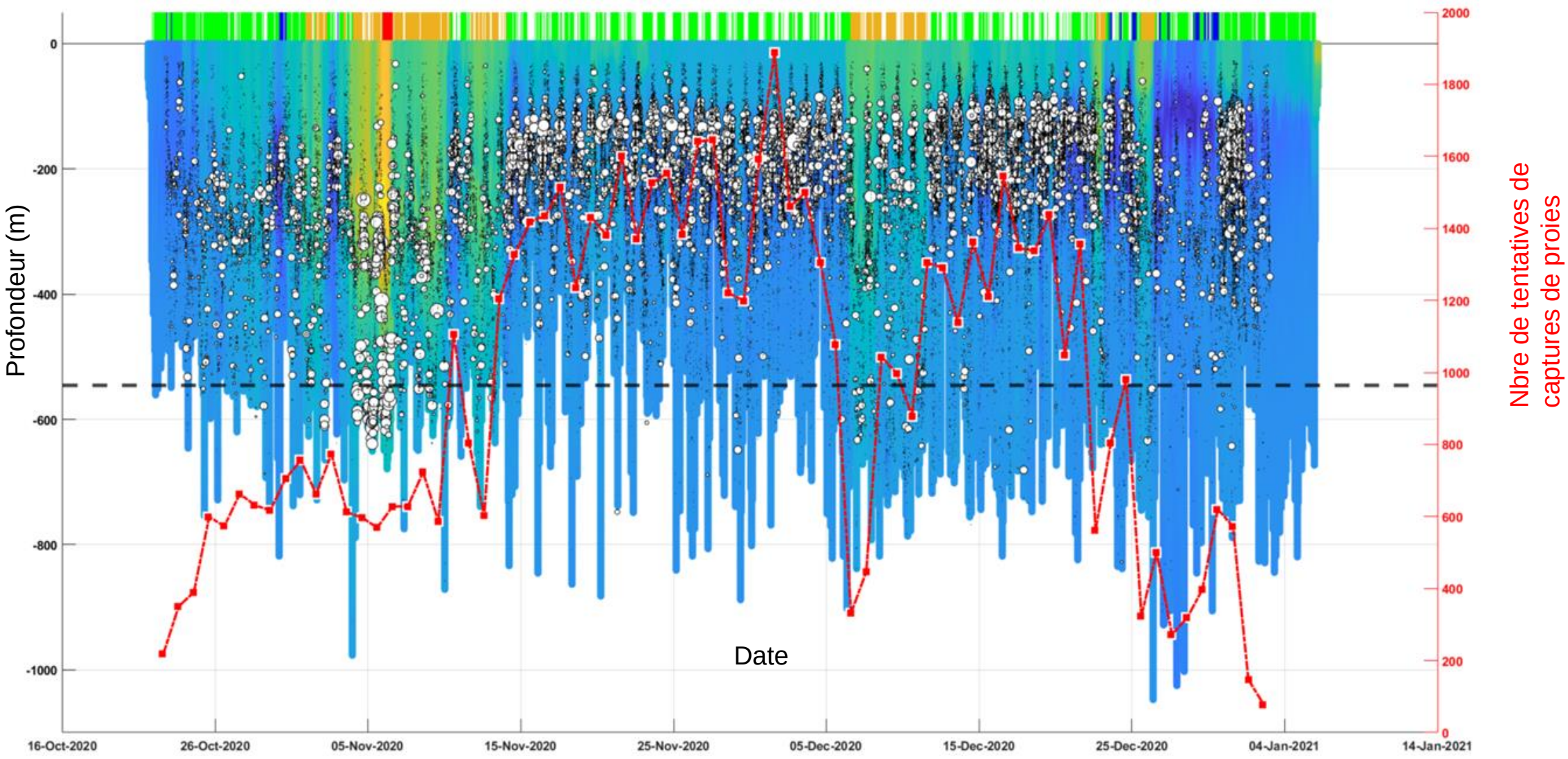
Chevallay et al. (2023)



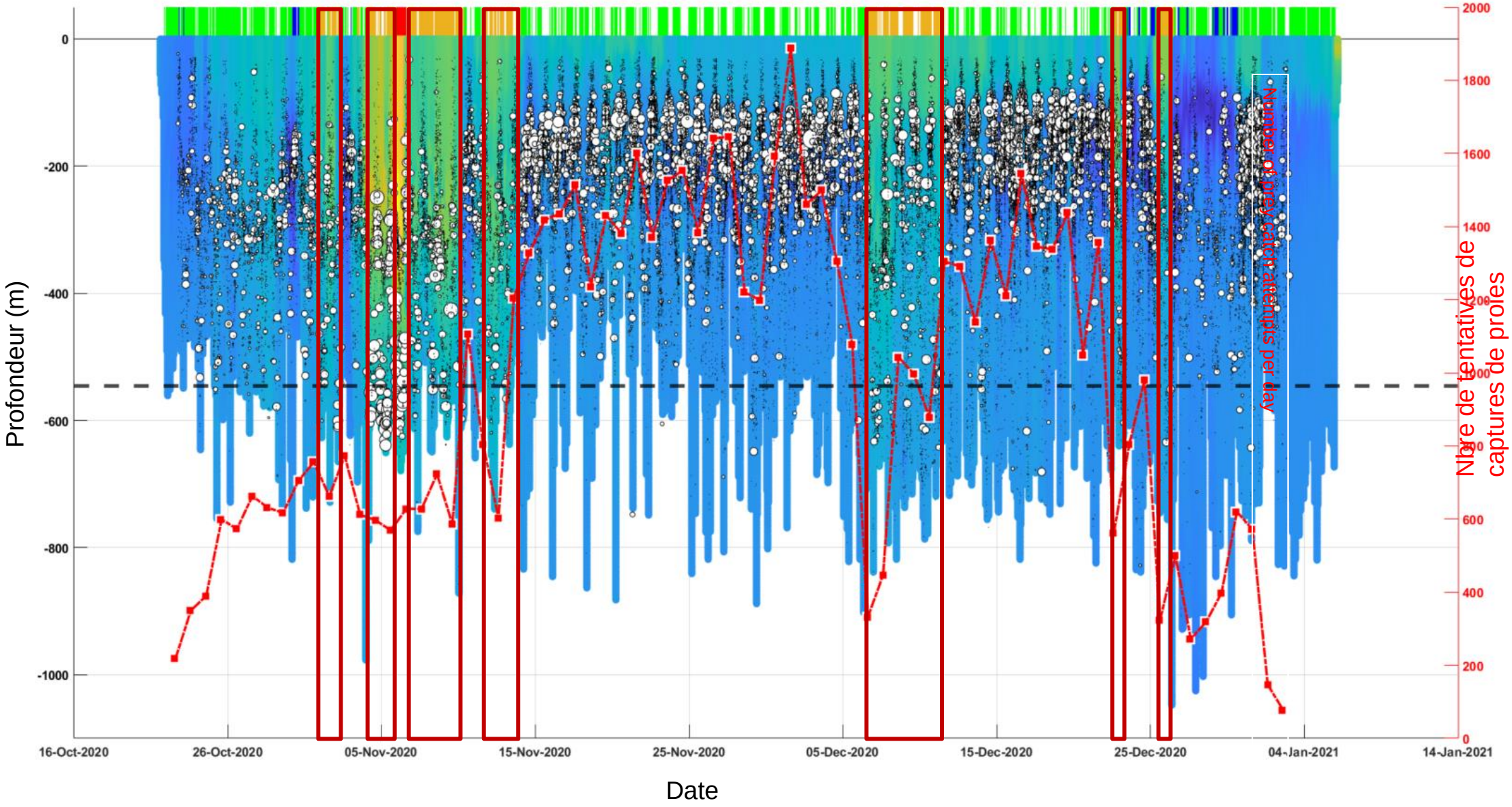




Bioluminescence Flash intensity = flash duration x Max intensity



Clabaux et al. (In prep)



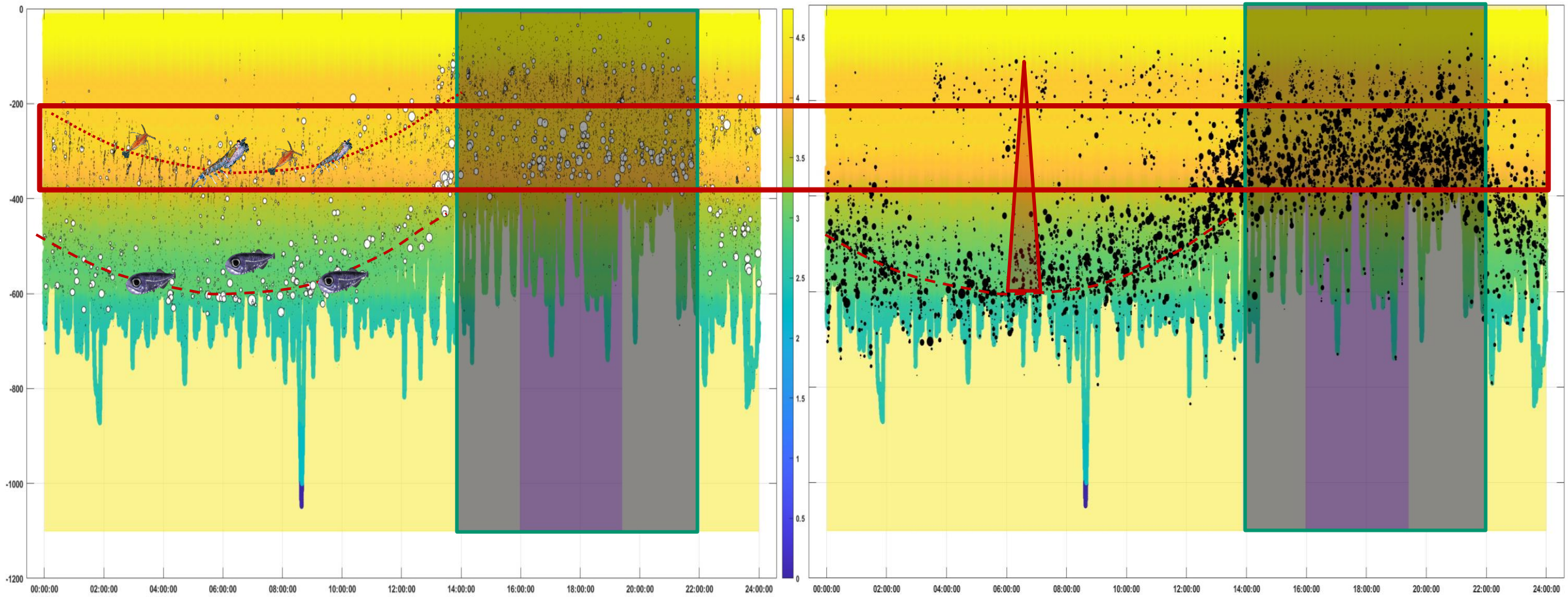
Clabaux et al. (In prep)

Bioluminescence

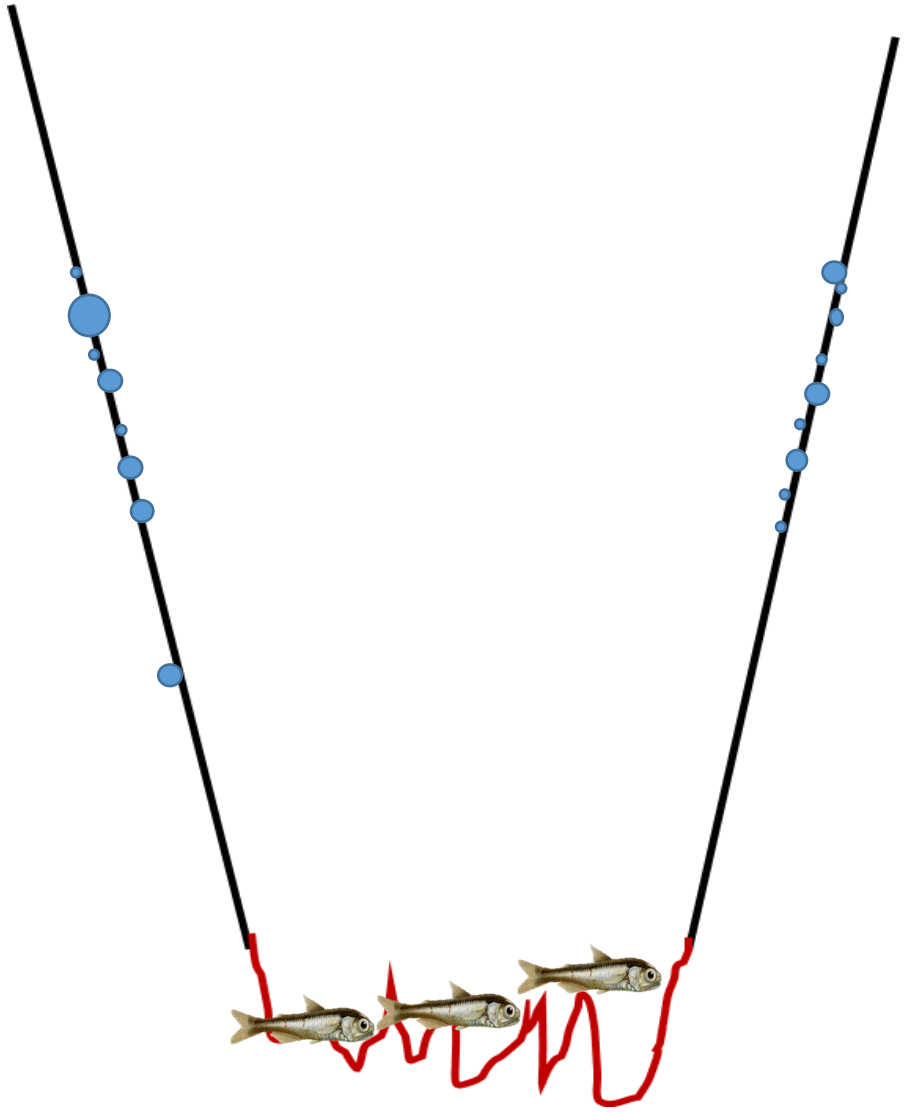
Prey Catch Attempts

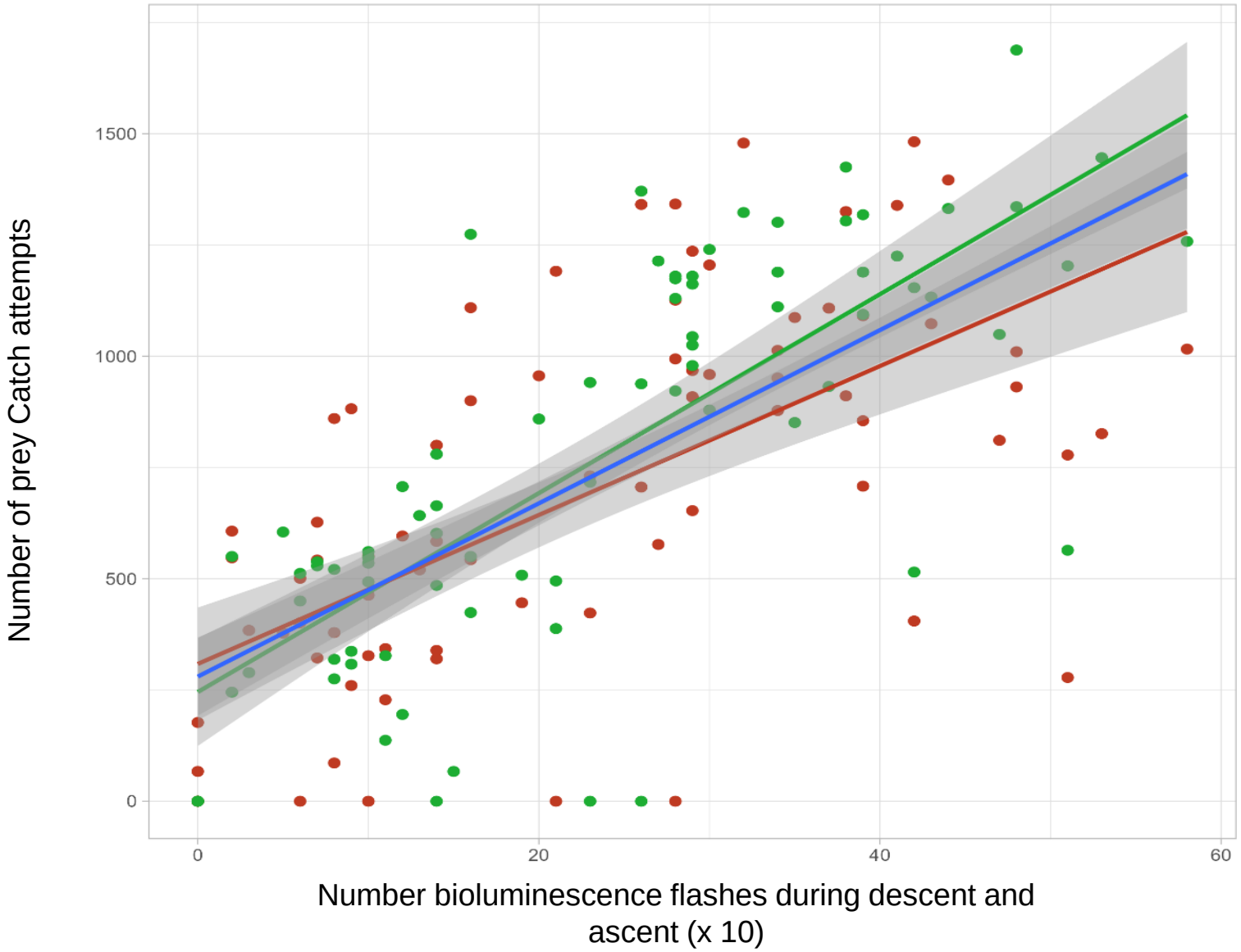
Day

Night

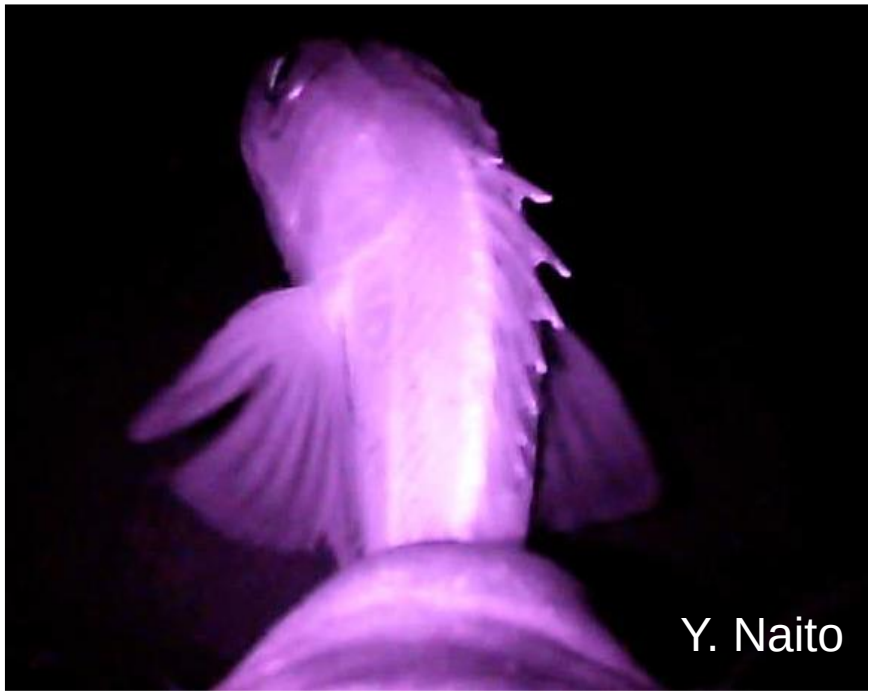


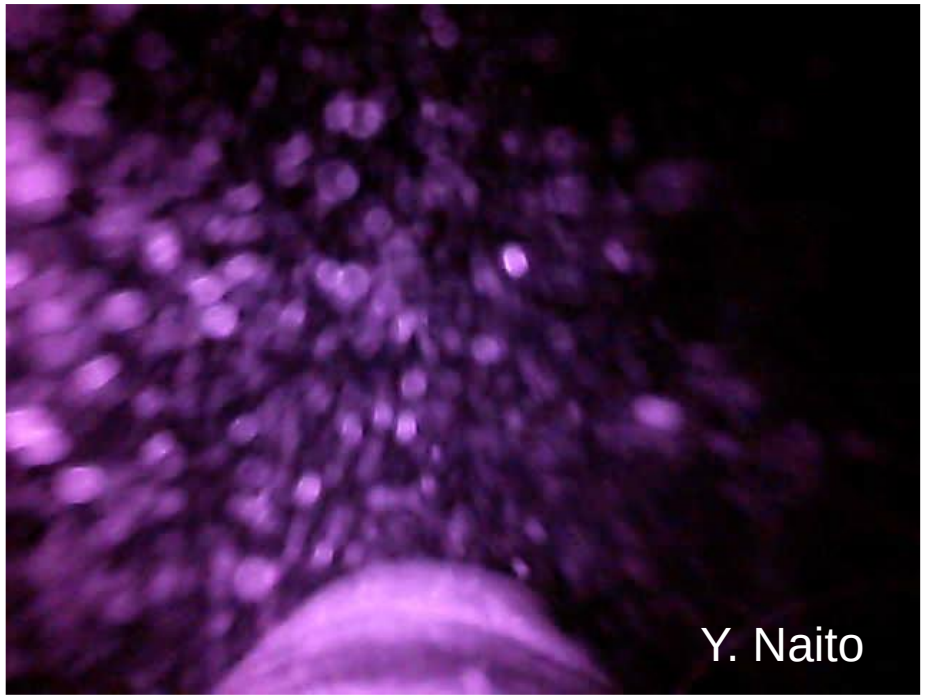
Goulet et al. J. Exp. Biol. (2020); Uzan et al. (to be submitted); Clabaux et al. (In prep)





Clabaux et al. (In prep)

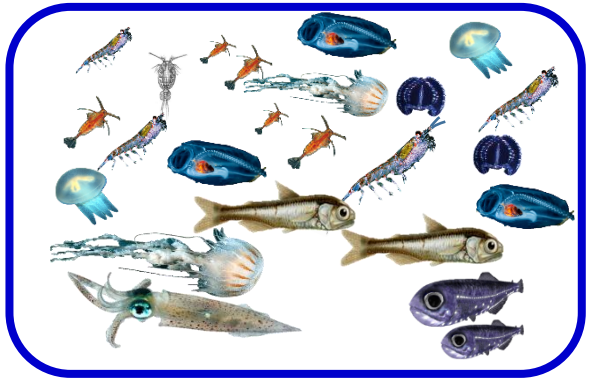




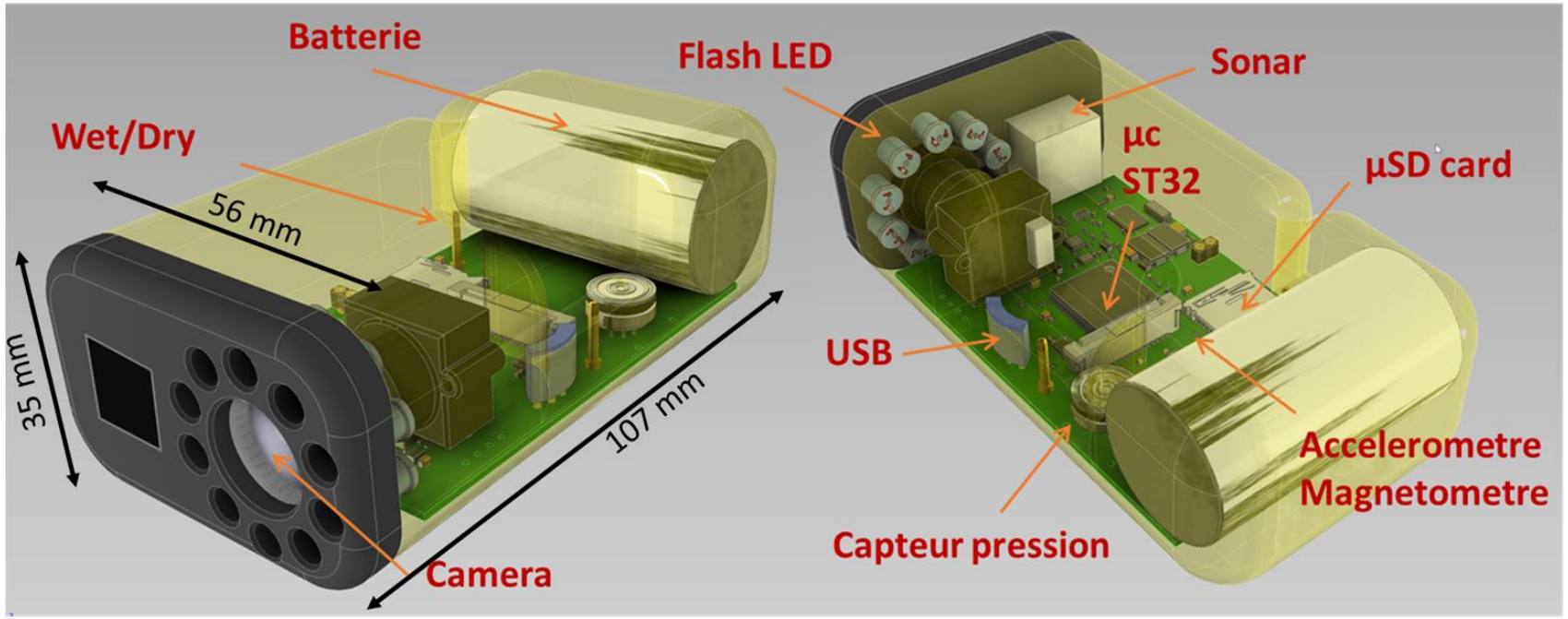
Des systèmes de caméra video (images pas suffisament nette pour permettre l’identification des petits organismes (zooplankton)

L'A2V-µCam : Combining a micro-sonar and a camera

Biologging-Lab



Mieux caractériser les niveaux trophiques intermédiaires



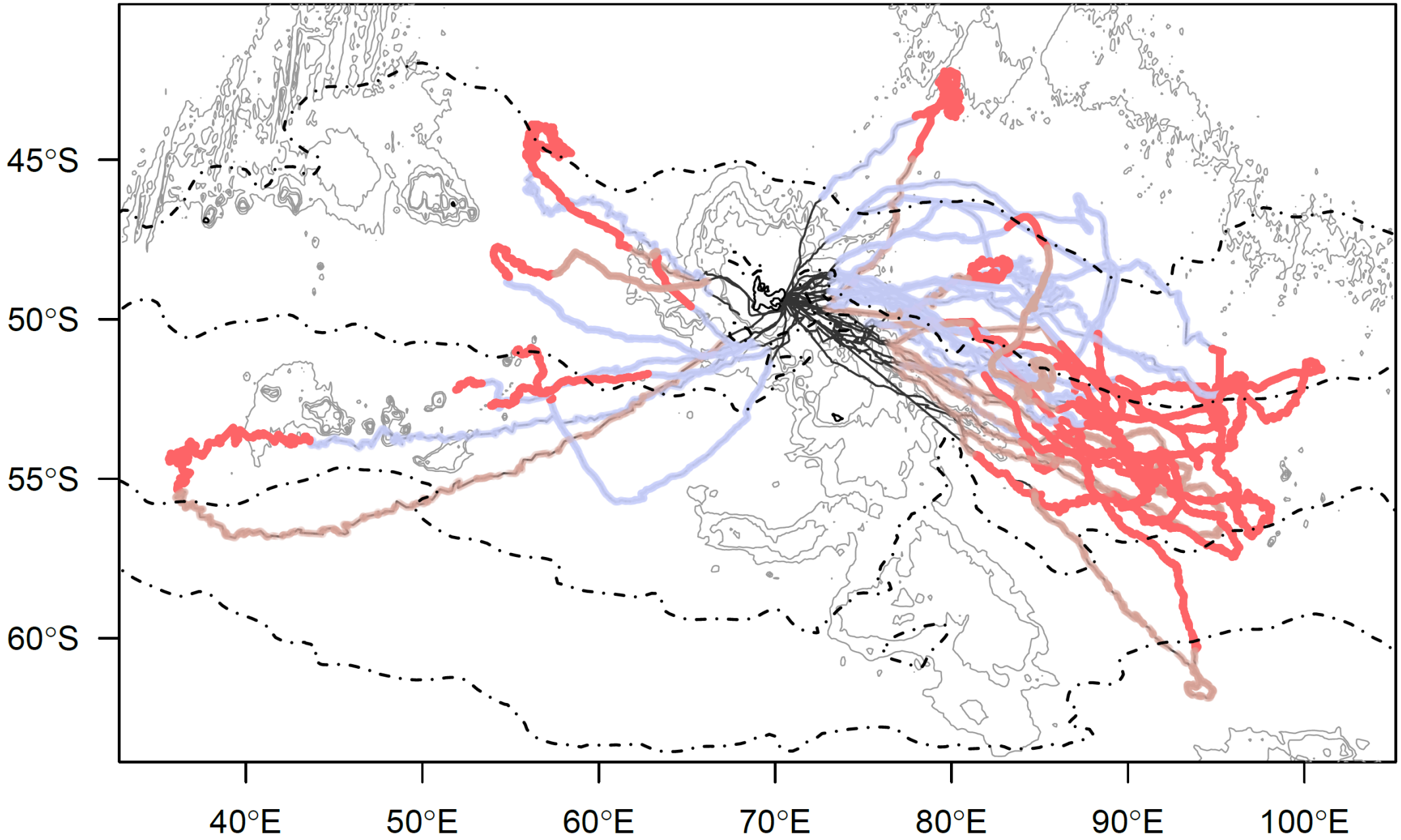
Conclusion:

- Développer de nouveaux biologger pour mieux évaluer la composante biologique de l'Océan Austral,

- Pour essayer de comprendre comment la compositon et l'abondance de la communauté mésopélagique change en fonction des conditions océanographiques

- Tout en étudiant l'incroyable écologie de cette espèce


Questions?


45°S
50°S
55°S
60°S
40°E
50°E
60°E
70°E
80°E
90°E
100°E

Les éléphants de mer plus longtemps demeurent dans des communautés de phytoplancton dominées par la presence de diatomées (Class 5), jusqu'à 45 jours consécutifs

Ziad Sari el Dine, PhD
LOG-CEBC

C3
47%
C4
15%
C5
33%
C6
05%

C5
100%

C5
100%

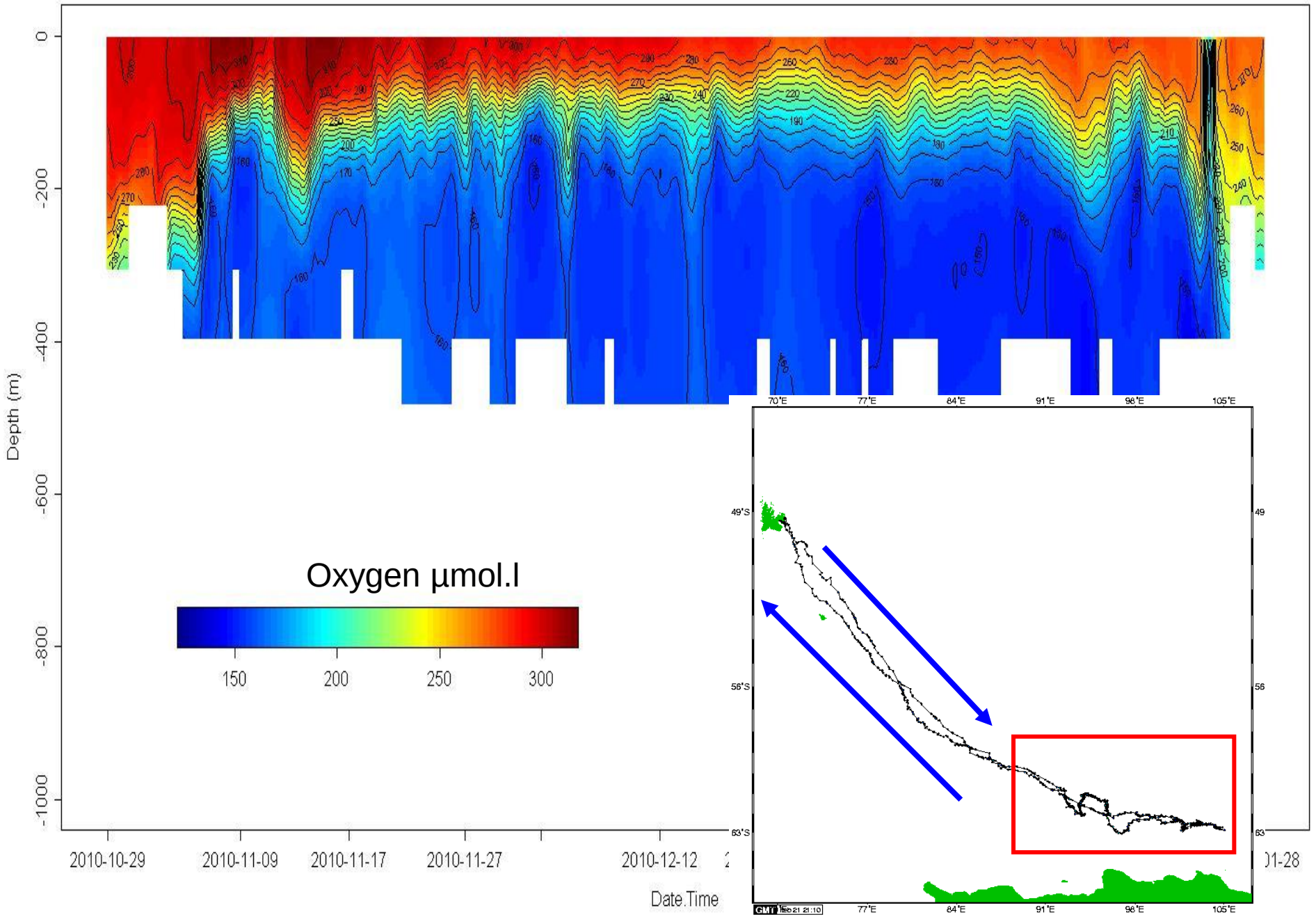
[0 – 5] [5 – 10] [10 – 15] [15 – 20] [> 20]

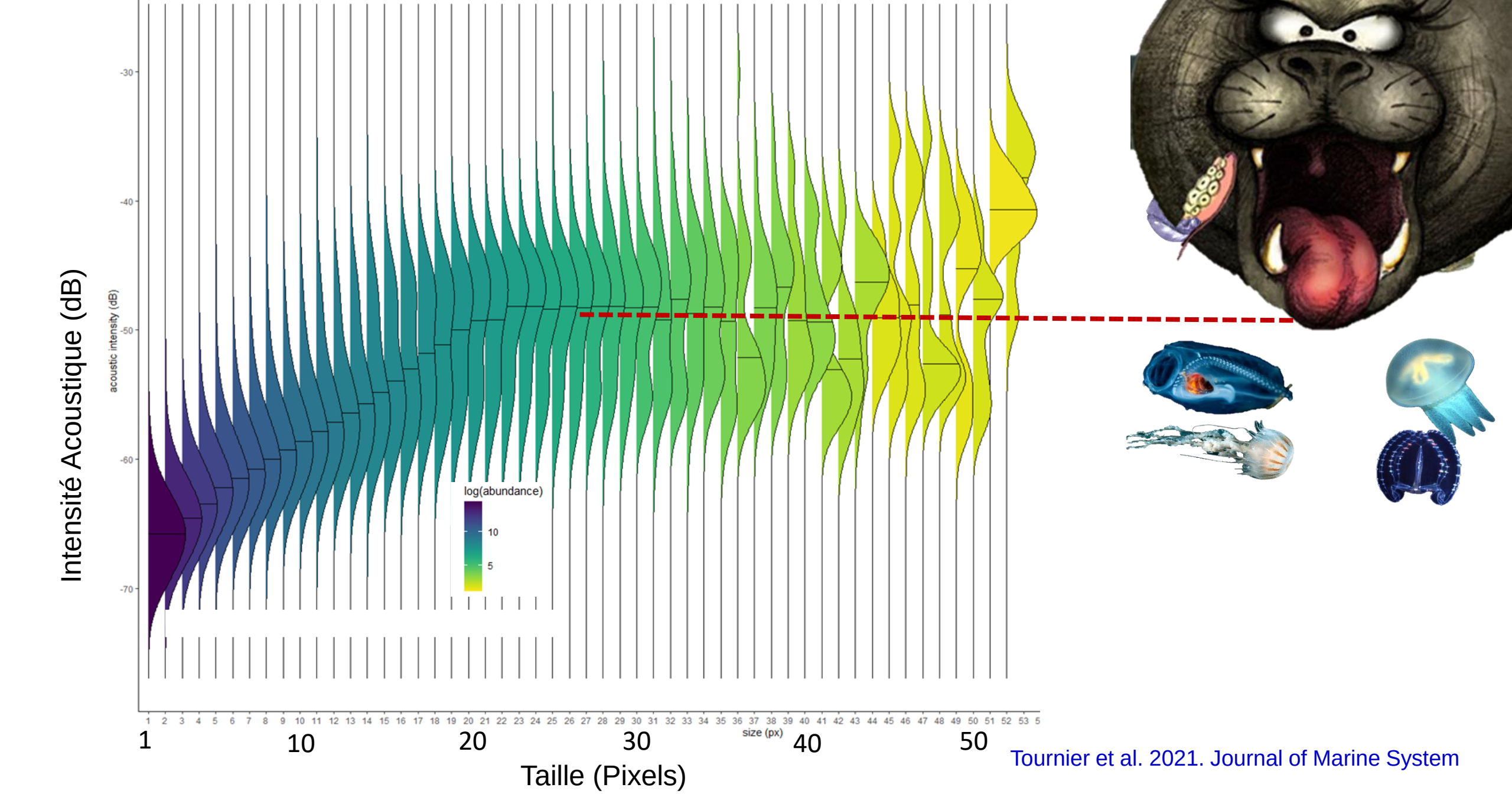
C3
33%
C4 11%
C5
56%

C5
100%

Nombre de jours consécutifs passes au sein d'une même classe

Sari el Dine, Soumis. Bio. Comm.


Depth (m)
0
-200
-400
-600
-800
-1000
2010-10-29
2010-11-09
2010-11-17
2010-11-27
2010-12-12
Date.Time
Oxygen µmol.l
150
200
250
300
70°E
77°E
84°E
91°E
98°E
105°E
49°S
56°S
63°S

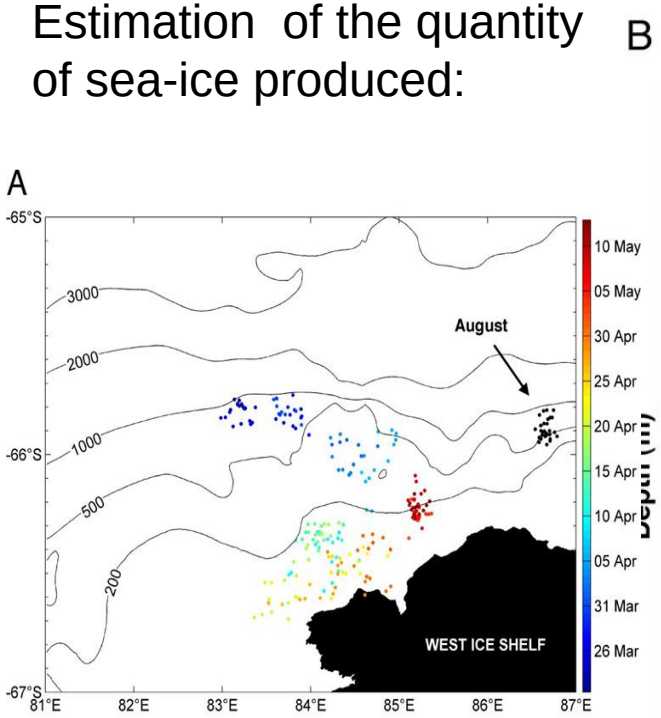


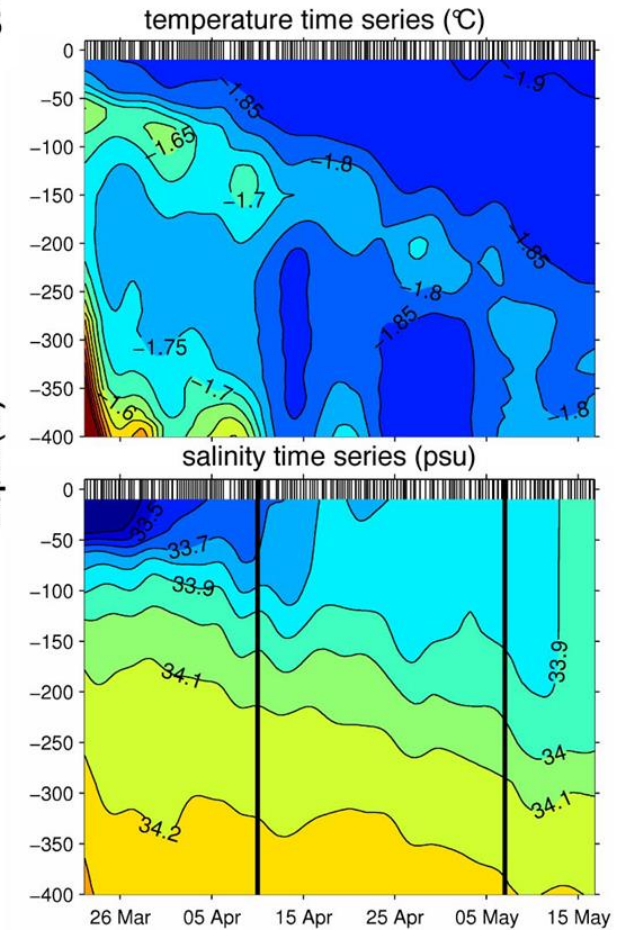
Tournier et al. 2021. Journal of Marine System

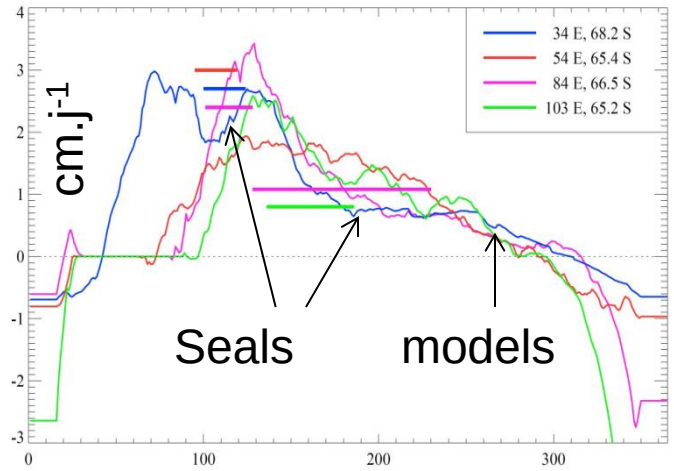
Molinet et al. (Soumis). Progress in Oceanography

Sea-Ice extent and thickness (CRYOSAT)

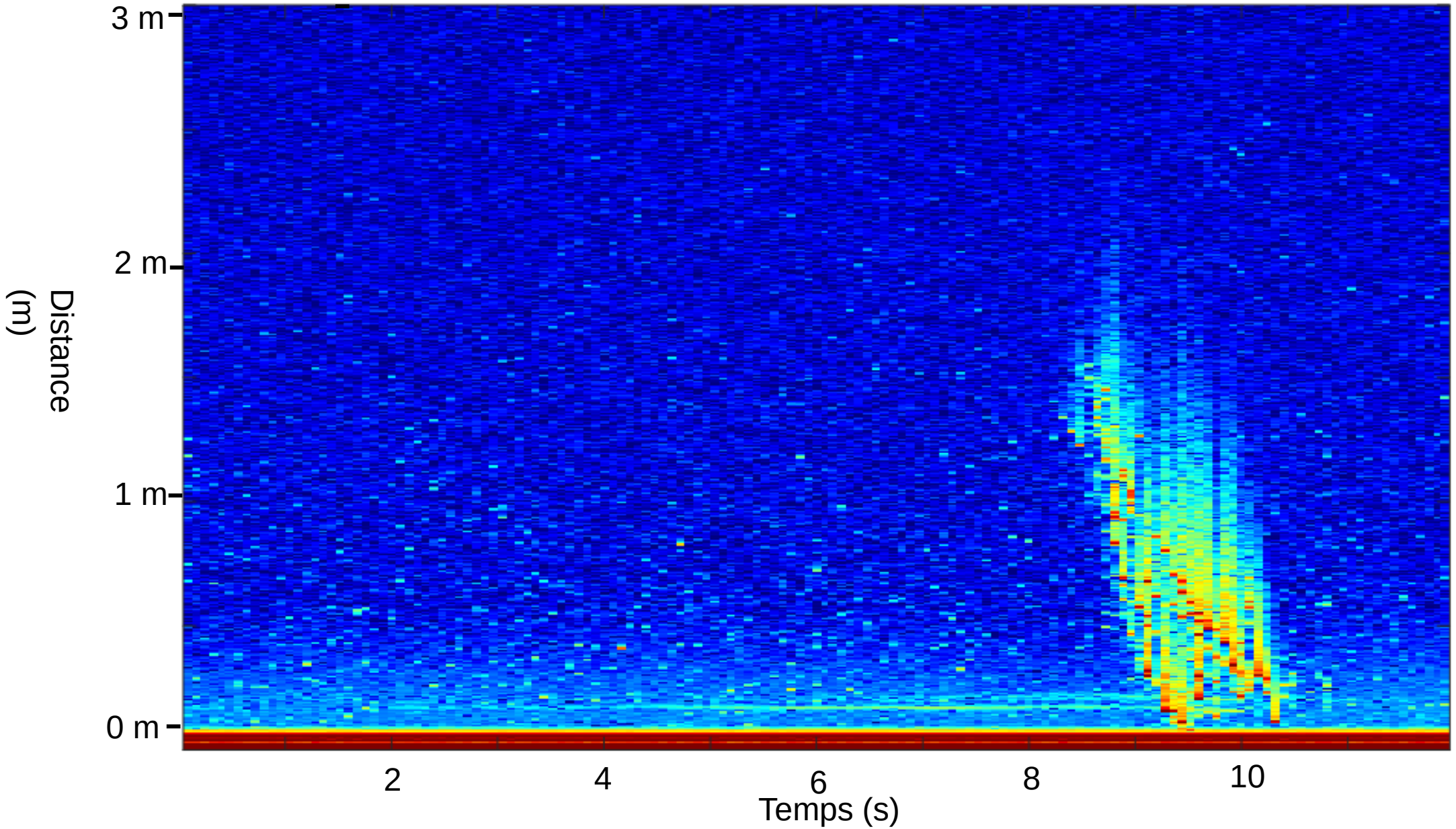
Estimation of the quantity of sea-ice produced:



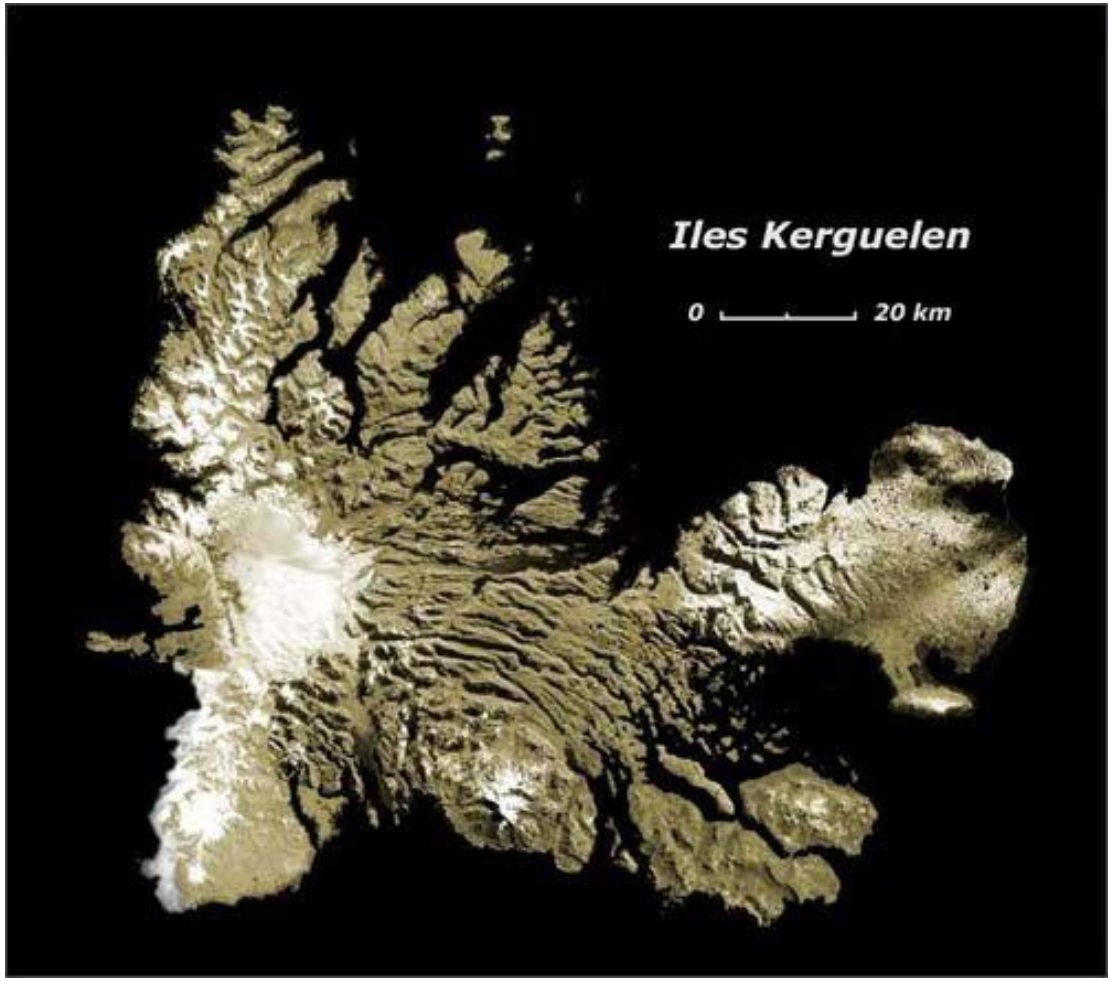




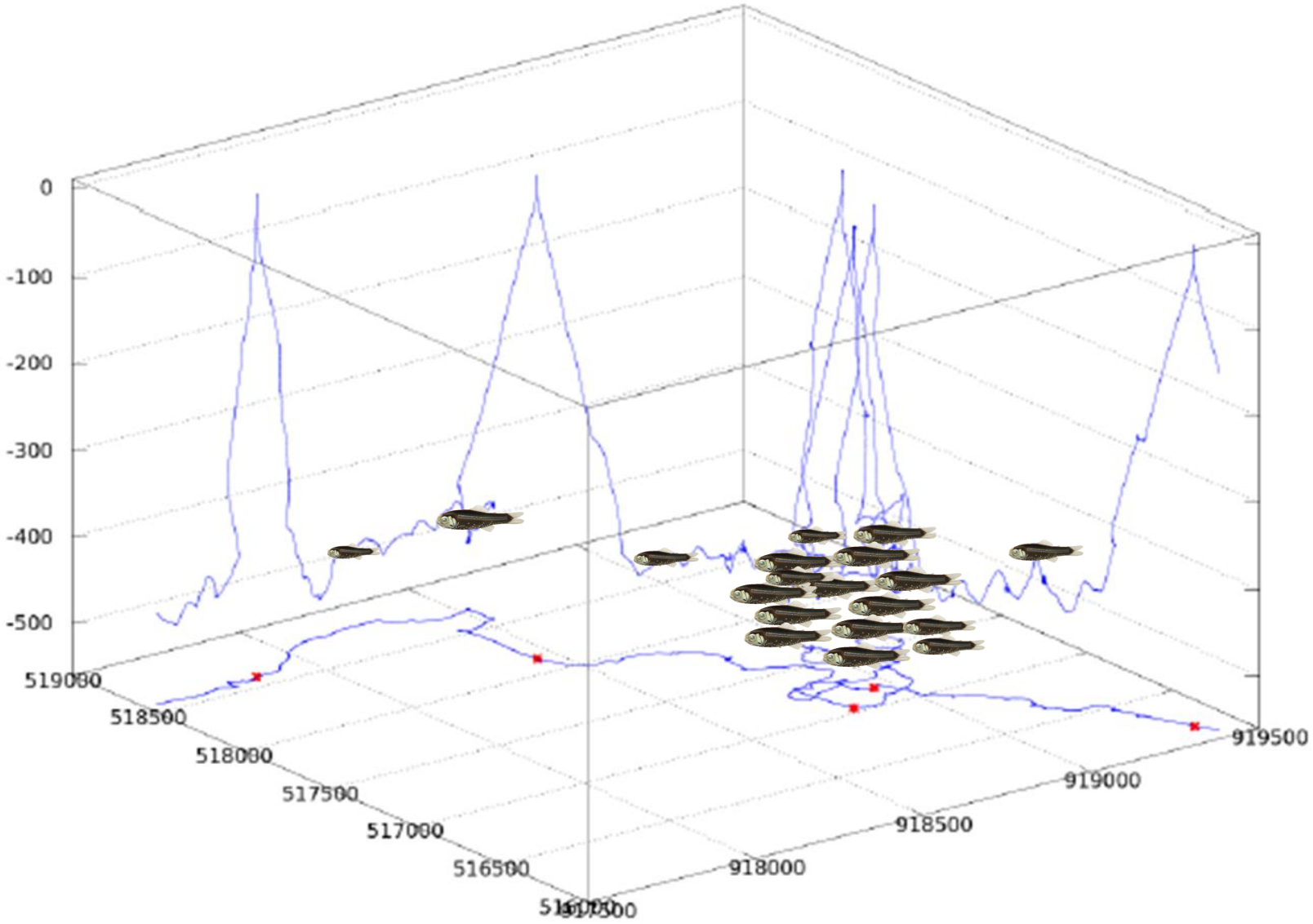
CHARRASSIN J.B., et al. (2008) Southern Ocean frontal structure and sea ice formation rates revealed by elephant seals. Proceedings of the National Academy of Sciences 105:11634-11639

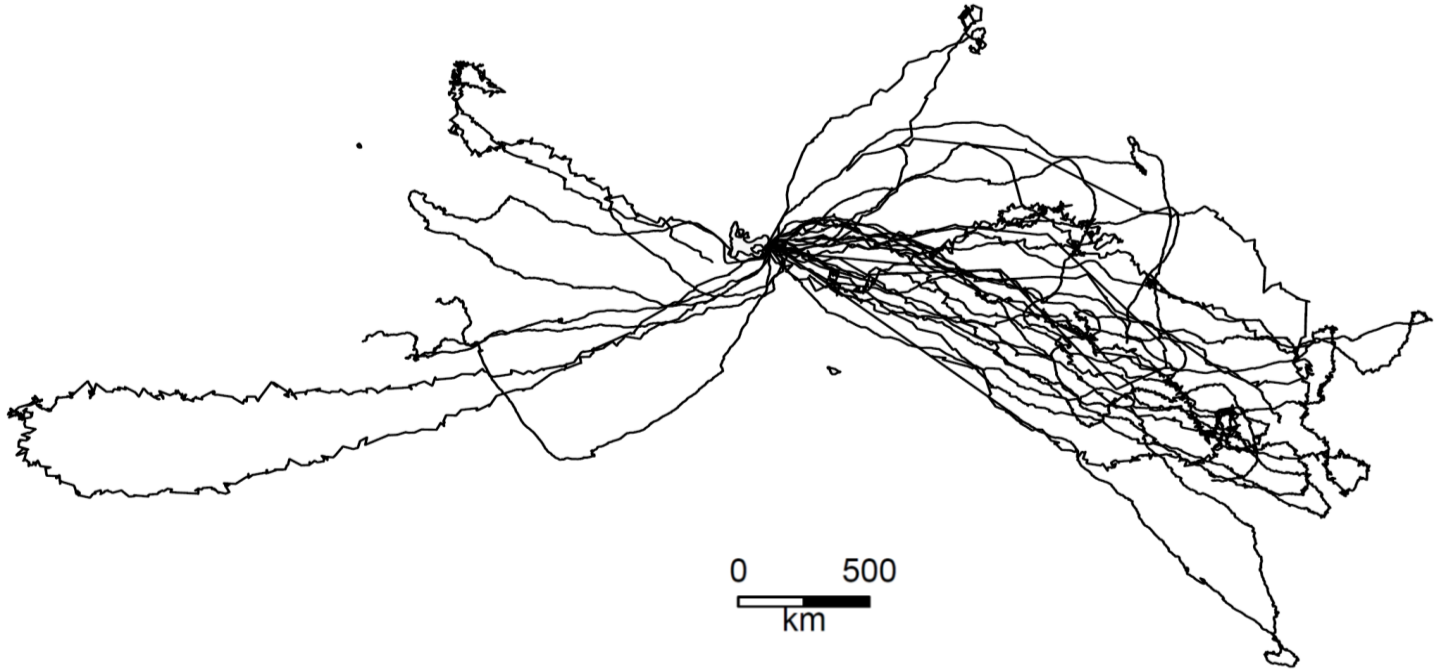

3 m
2 m
1 m
0 m
Distance (m)
2
4
6
8
10
Temps (s)

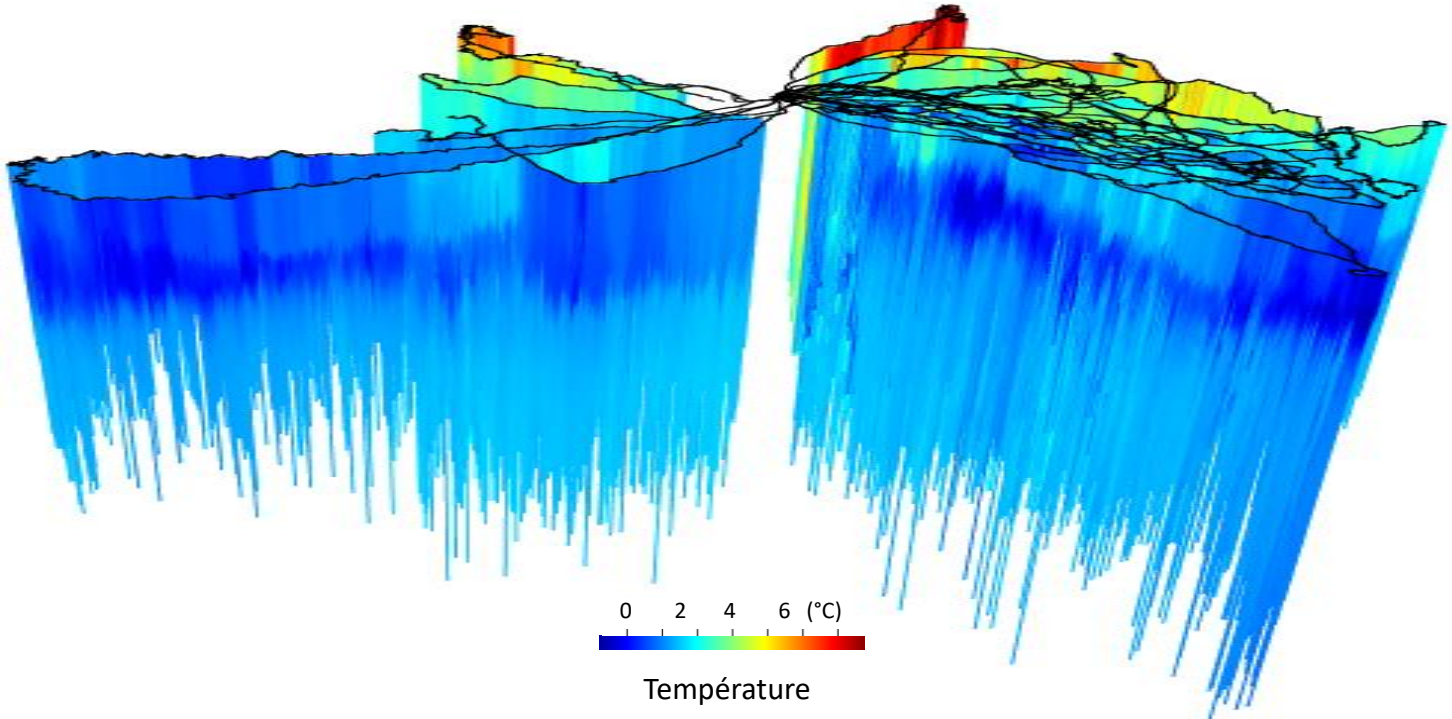
6. Elephant seal population change

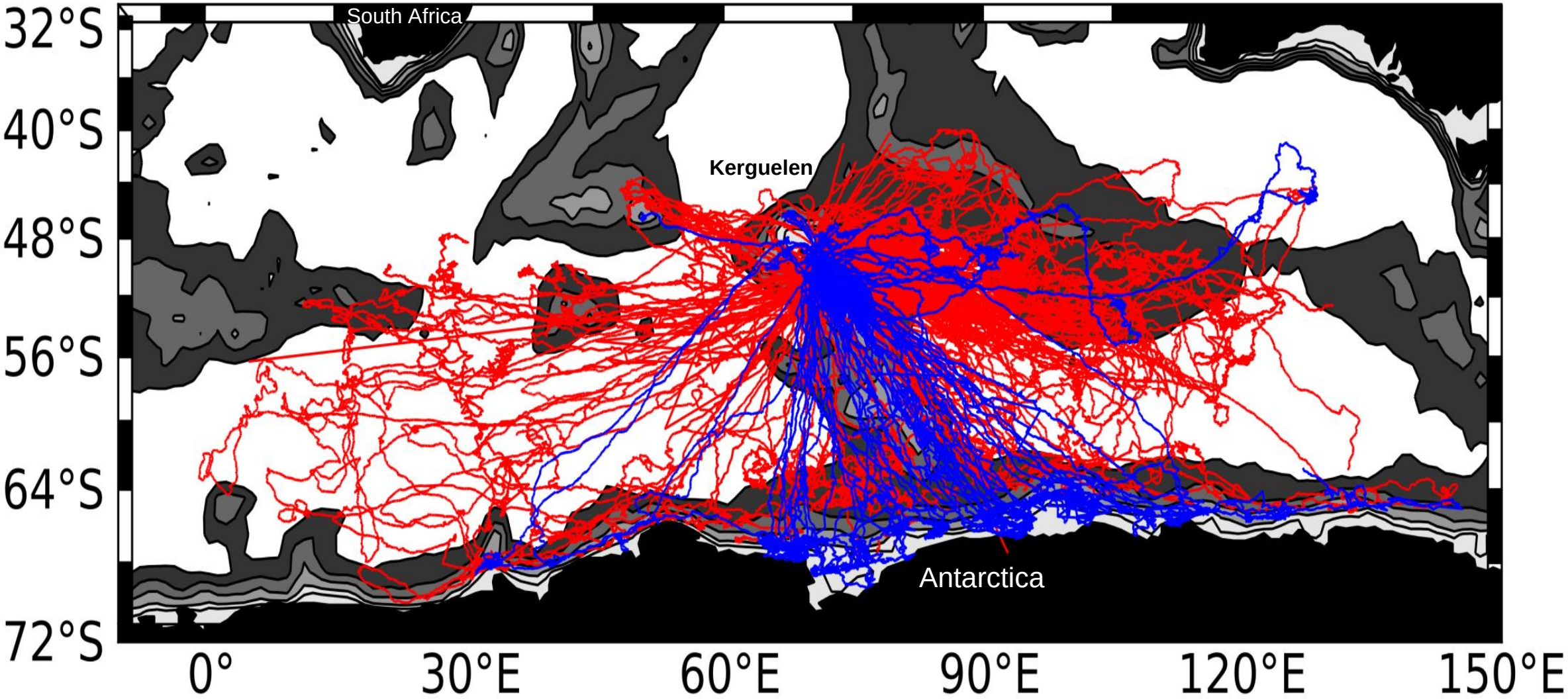


Reconstruction en trois dimensions de la trajectoire des plongées




0
500
km


0 2 4 6 (°C)
Température



The Global Ocean Observing System

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