Eléphants de mer bio-échantillonneurs des conditions océanographiques: mesure de nouveaux paramètres océanographiques et mesures biologiques

Christophe Guinet,

Tiphaine Jeanniard du Dot (CEBC), Baptiste Picard (CEBC) Dorian Cazau (ENSTA-Bretagne), Severine Martini (LOV), Pauline Goulet (SMRU), Mark Johnson (SMRU)

AEI Lille 9-11
Juillet 2019

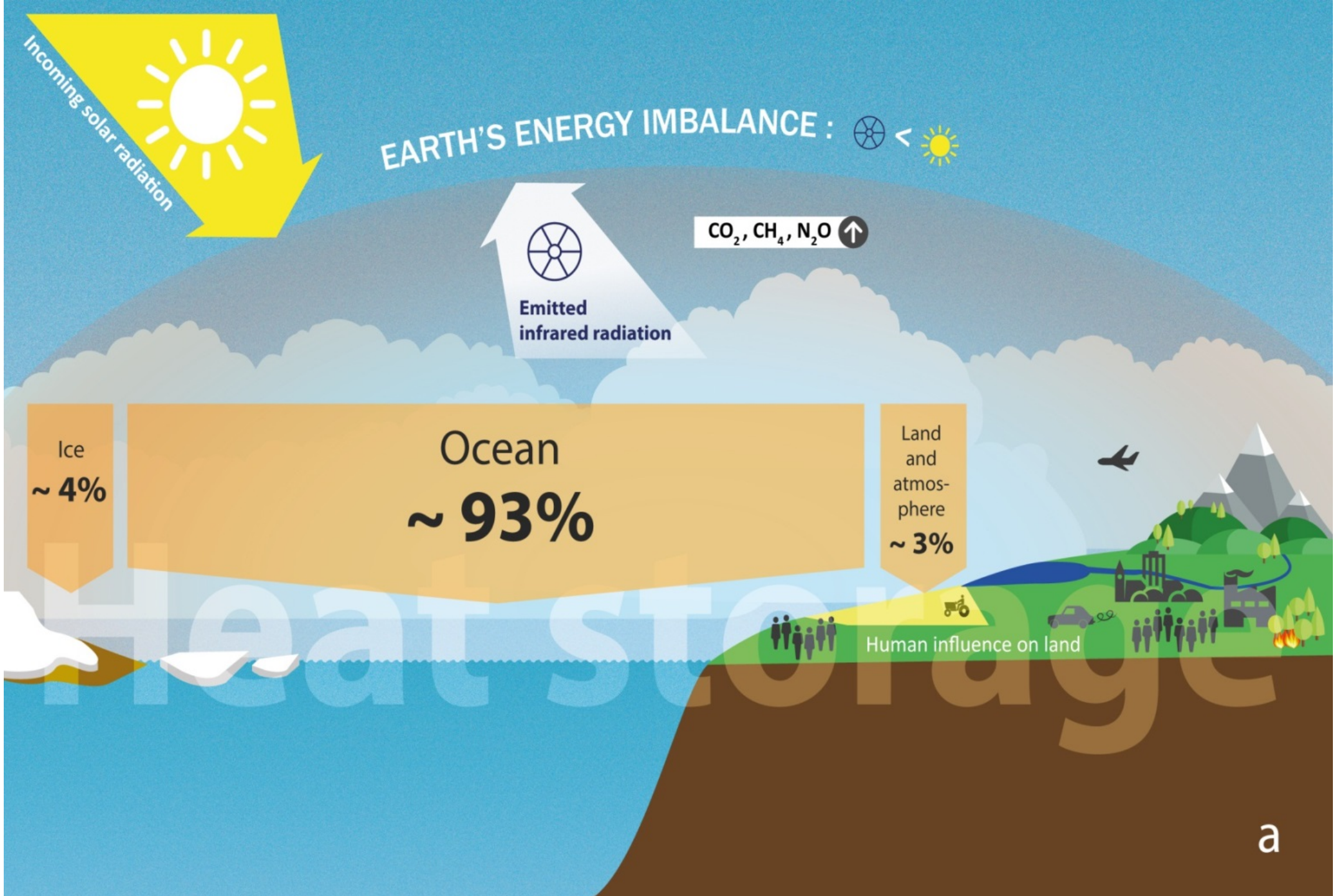




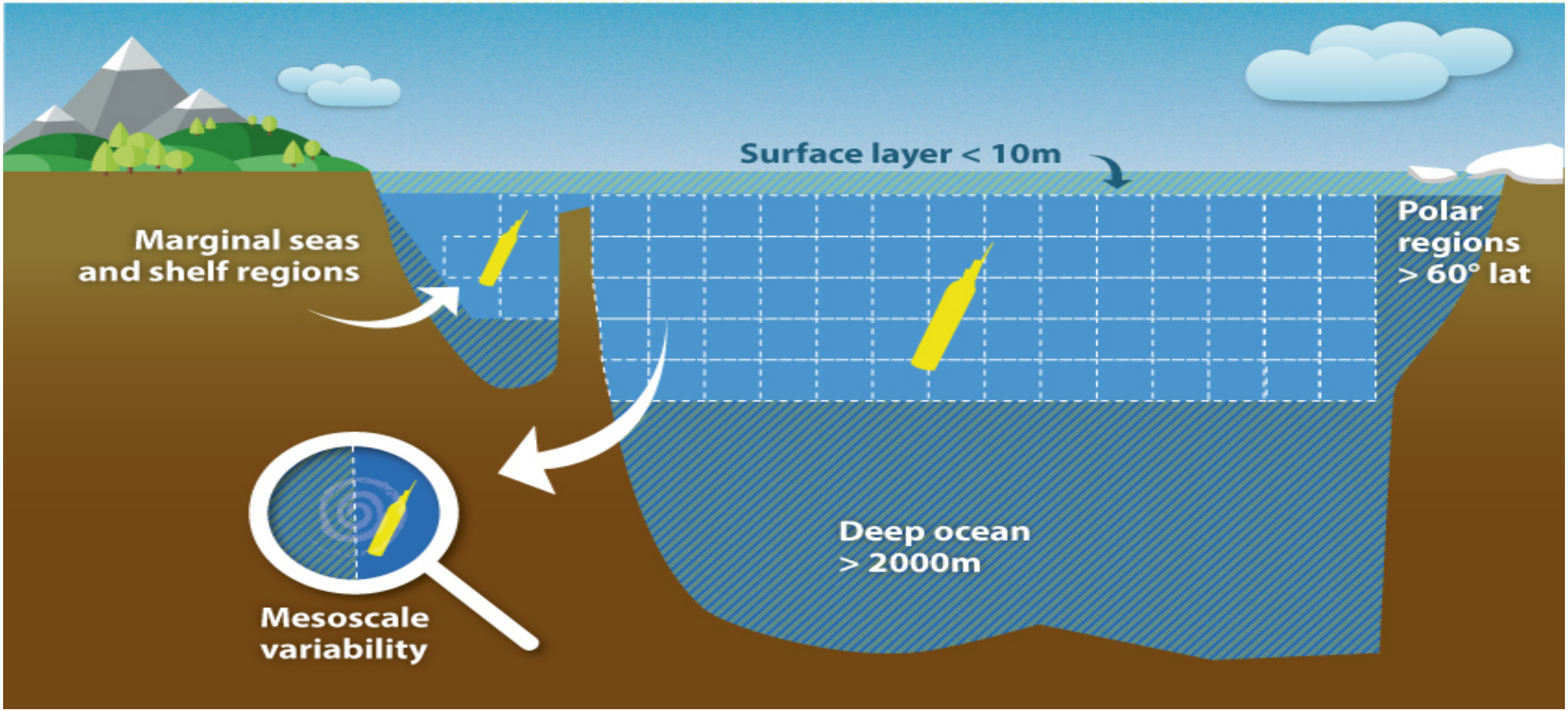


Dans un contexte de changements rapides :

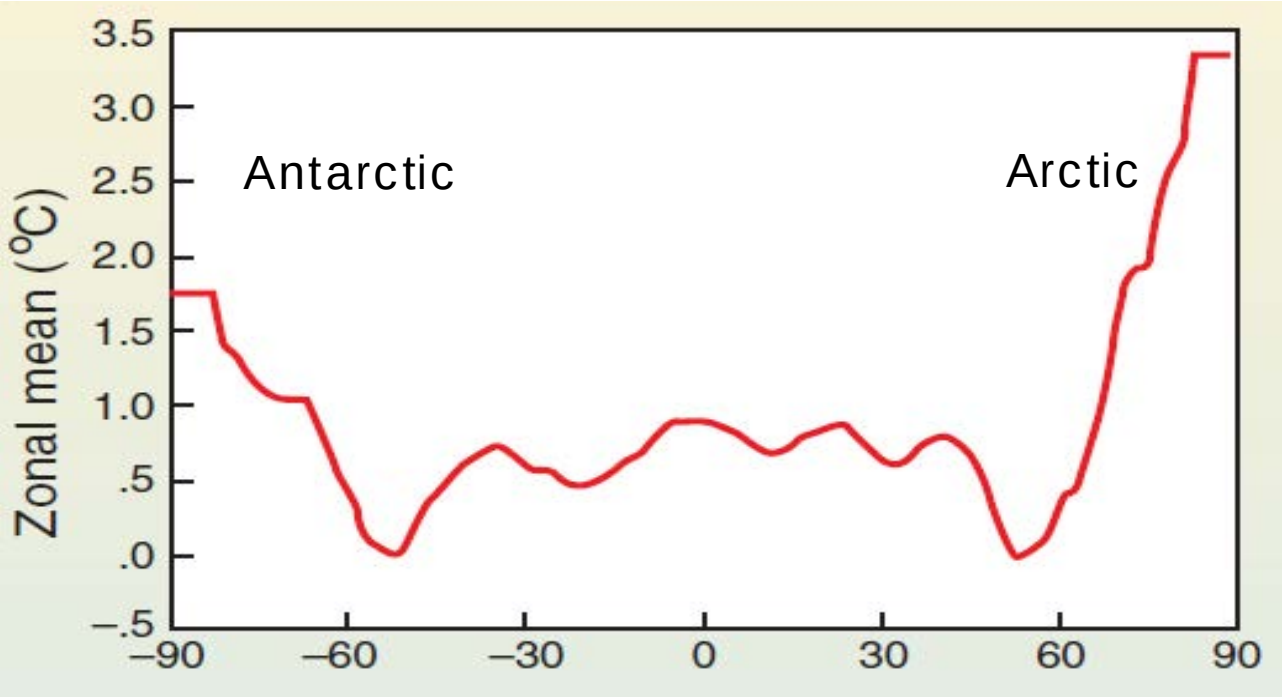
Les animaux marins deviennent de nouveaux auxiliaires pour observer et mieux comprendre le fonctionnement et les changements qui affectent l’océan

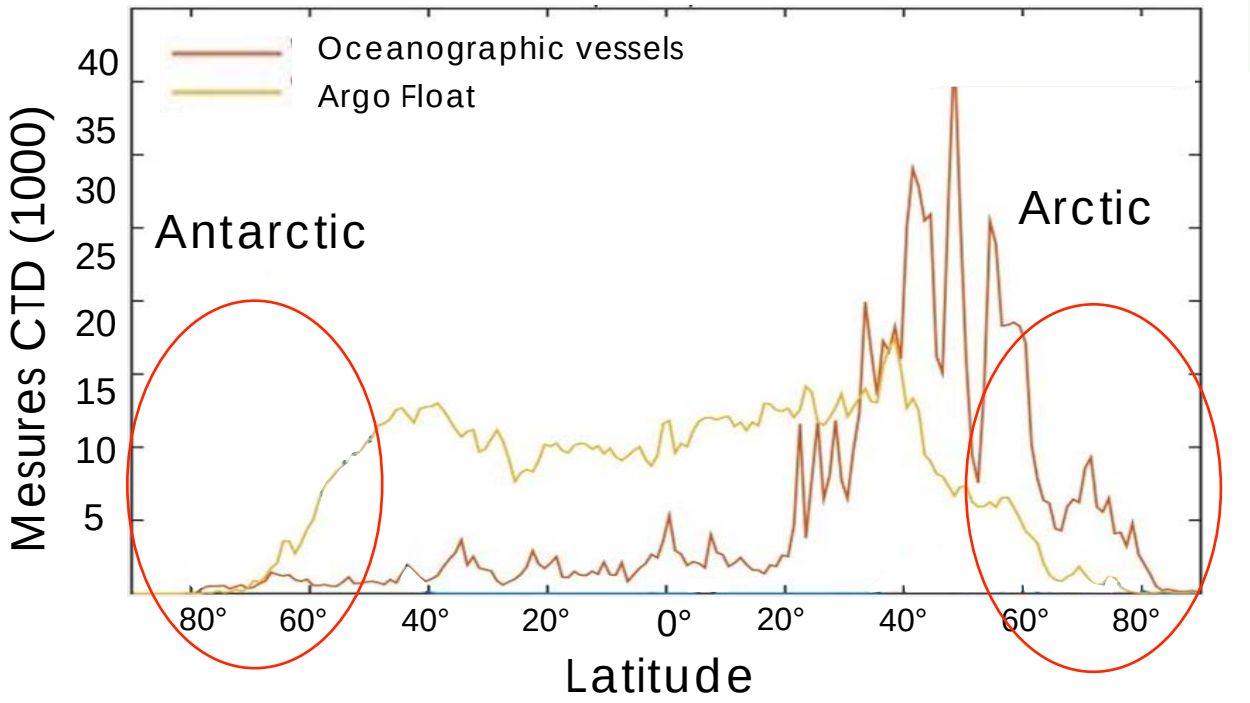

Incoming solar radiation
EARTH'S ENERGY IMBALANCE : <
CO_2, CH_4, N_2O
Emitted infrared radiation
Ice ~ 4%
Ocean ~ 93%
Land and atmos-phere ~ 3%
Human influence on land
Heat storage
a

L'Océan Global:
Des zones sous observées

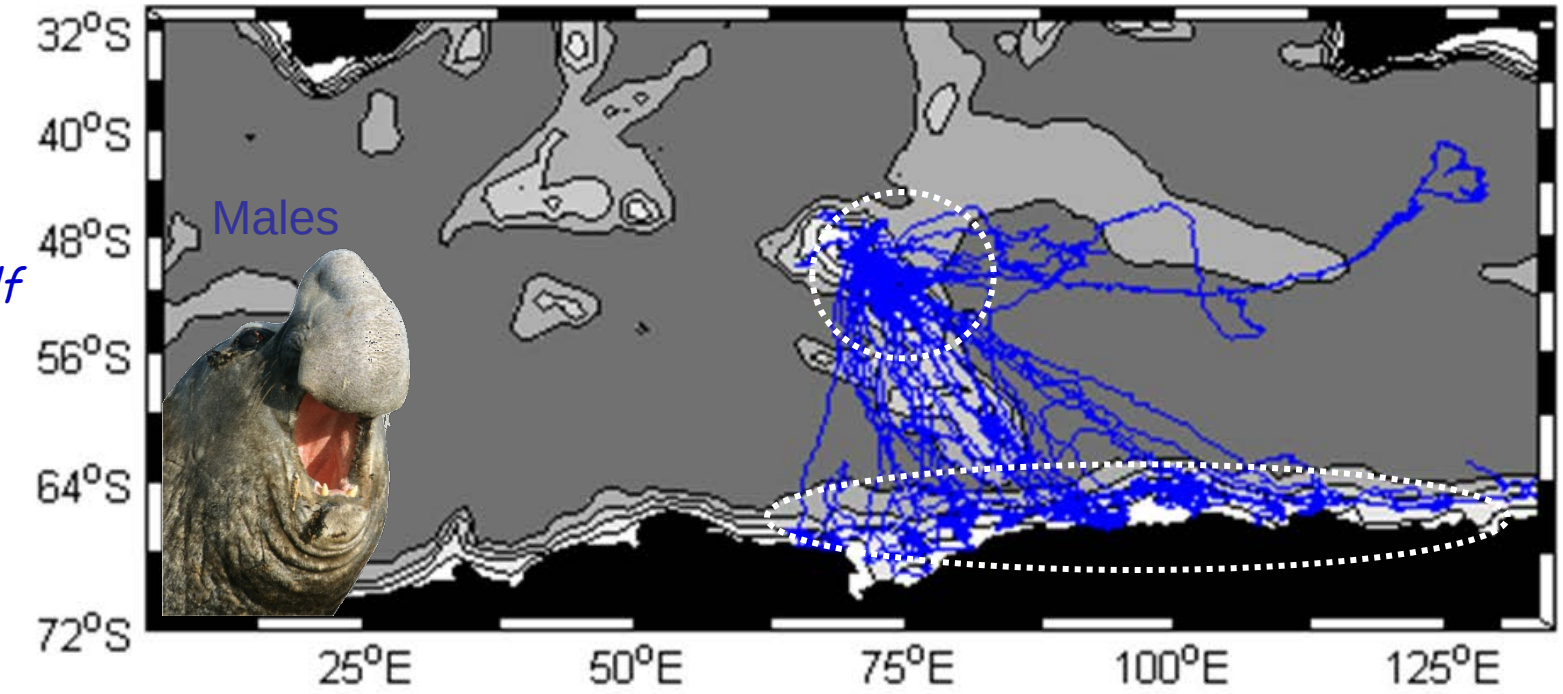


von Schuckmann at al., 2015, Nature Climate Change

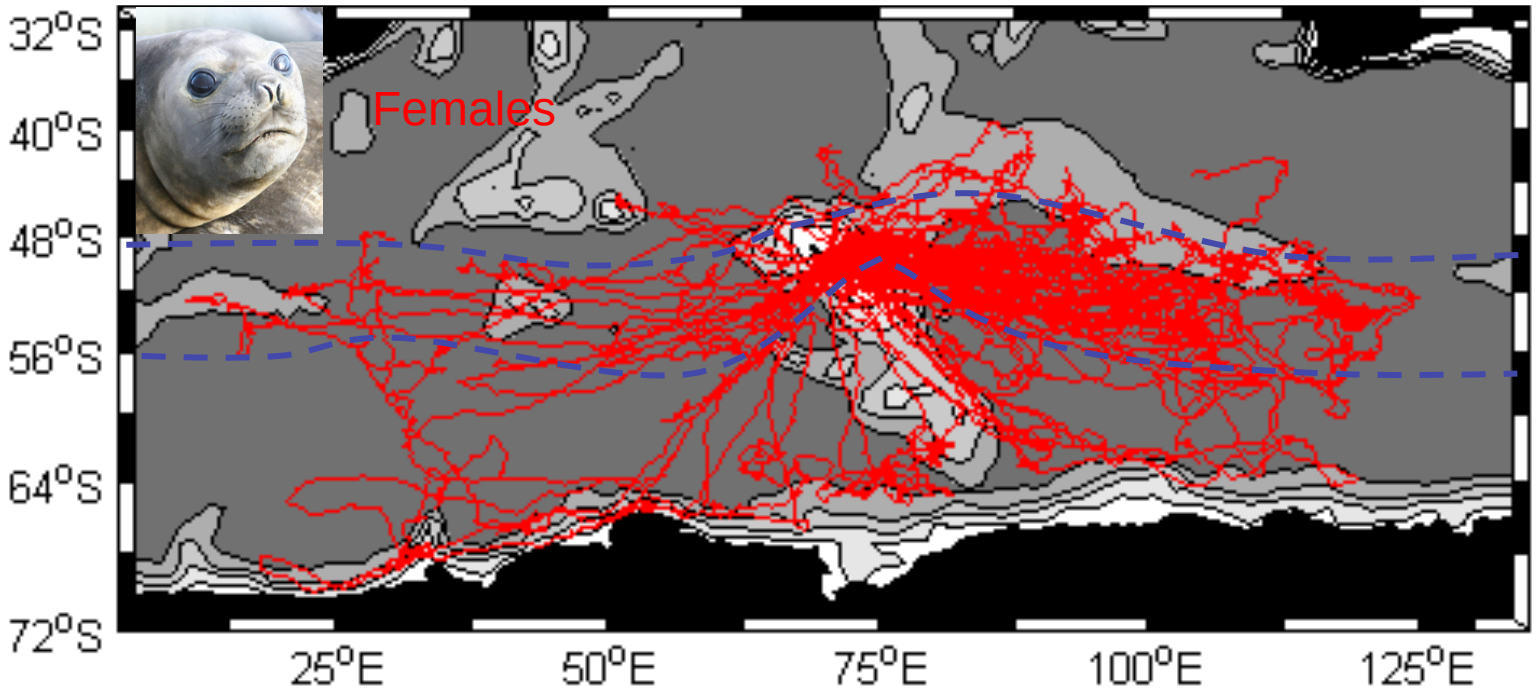

Zonal mean (°C)
3.5
3.0
2.5
2.0
1.5
1.0
.5
.0
–.5
Antarctic
Arctic
–90
–60
–30
0
30
60
90

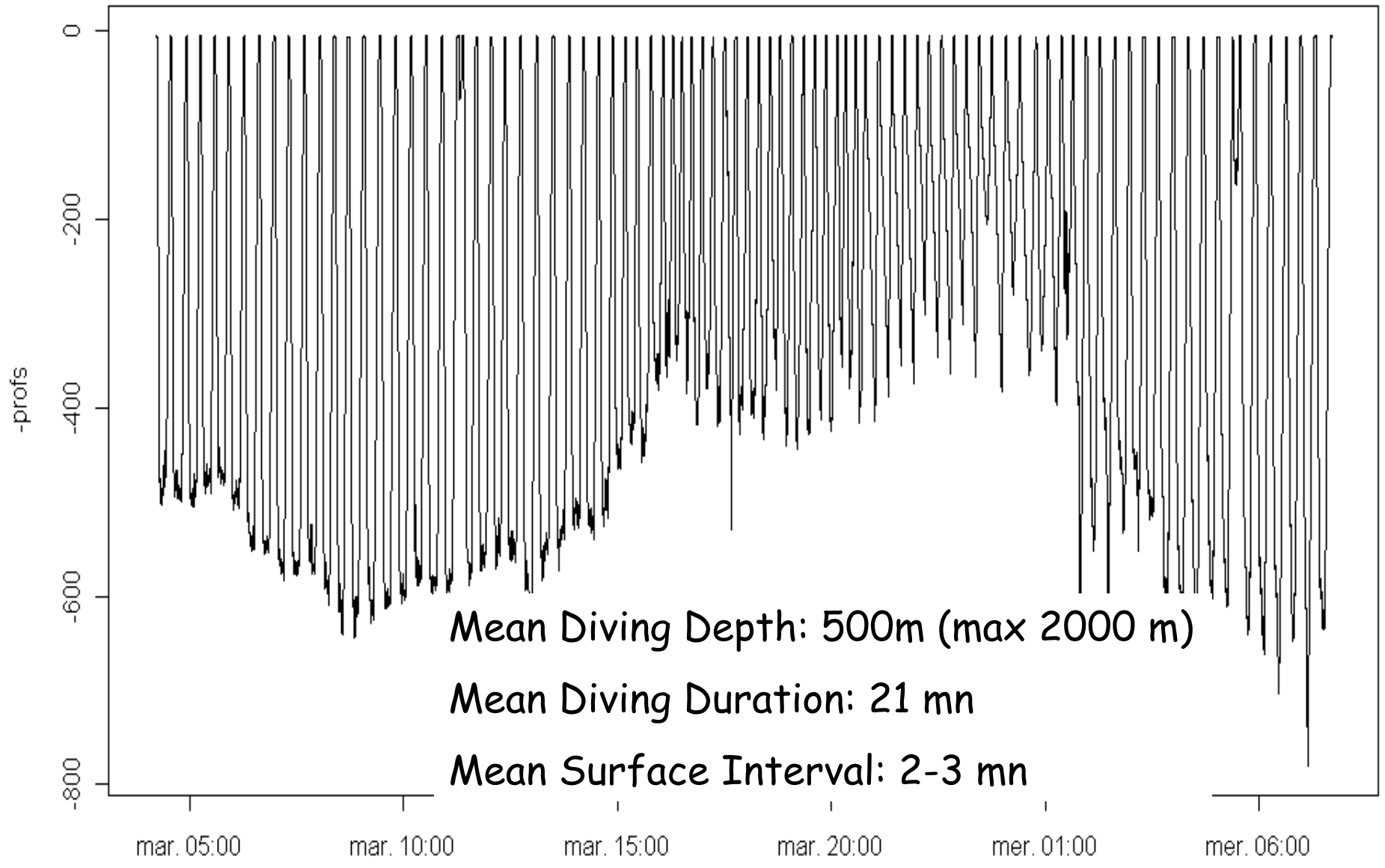

Oceanographic vessels
Argo Float
Mesures CTD (1000)
40
35
30
25
20
15
10
5
Antarctic
Arctic
80°
60°
40°
20°
0°
20°
40°
60°
80°
Latitude

Males
Benthic
Kerguelen &
Antarctic Shelf



Femelles
Pelagic
Polar frontal Zone
Sea Ice Zone



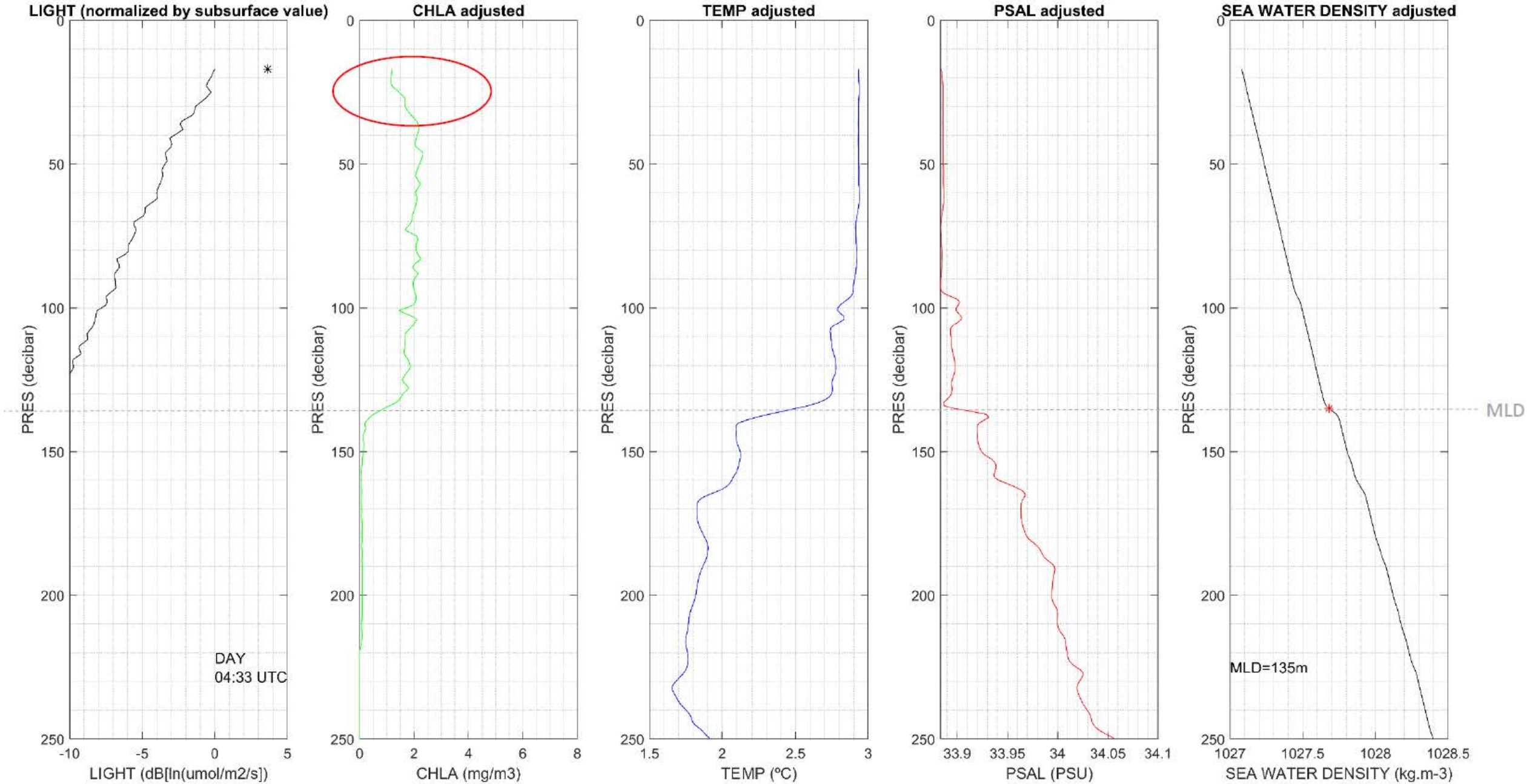

-profs
0
-200
-400
-600
-800
mar. 05:00
mar. 10:00
mar. 15:00
mar. 20:00
mer. 01:00
mer. 06:00
Mean Diving Depth: 500m (max 2000 m)
Mean Diving Duration: 21 mn
Mean Surface Interval: 2-3 mn

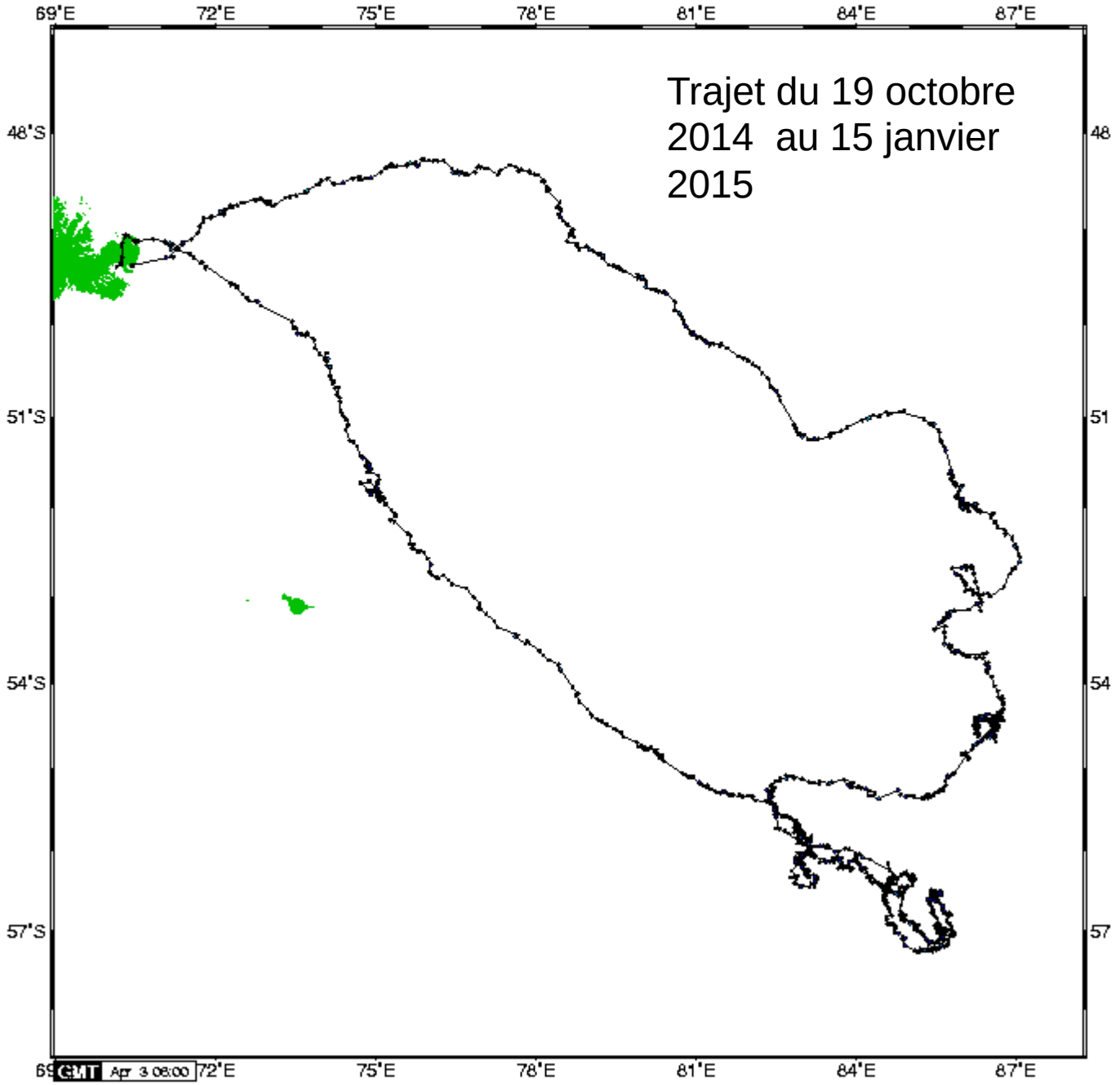
Argos Transmitted (2-4 profiles/day), 24 T/S points/profile, real time

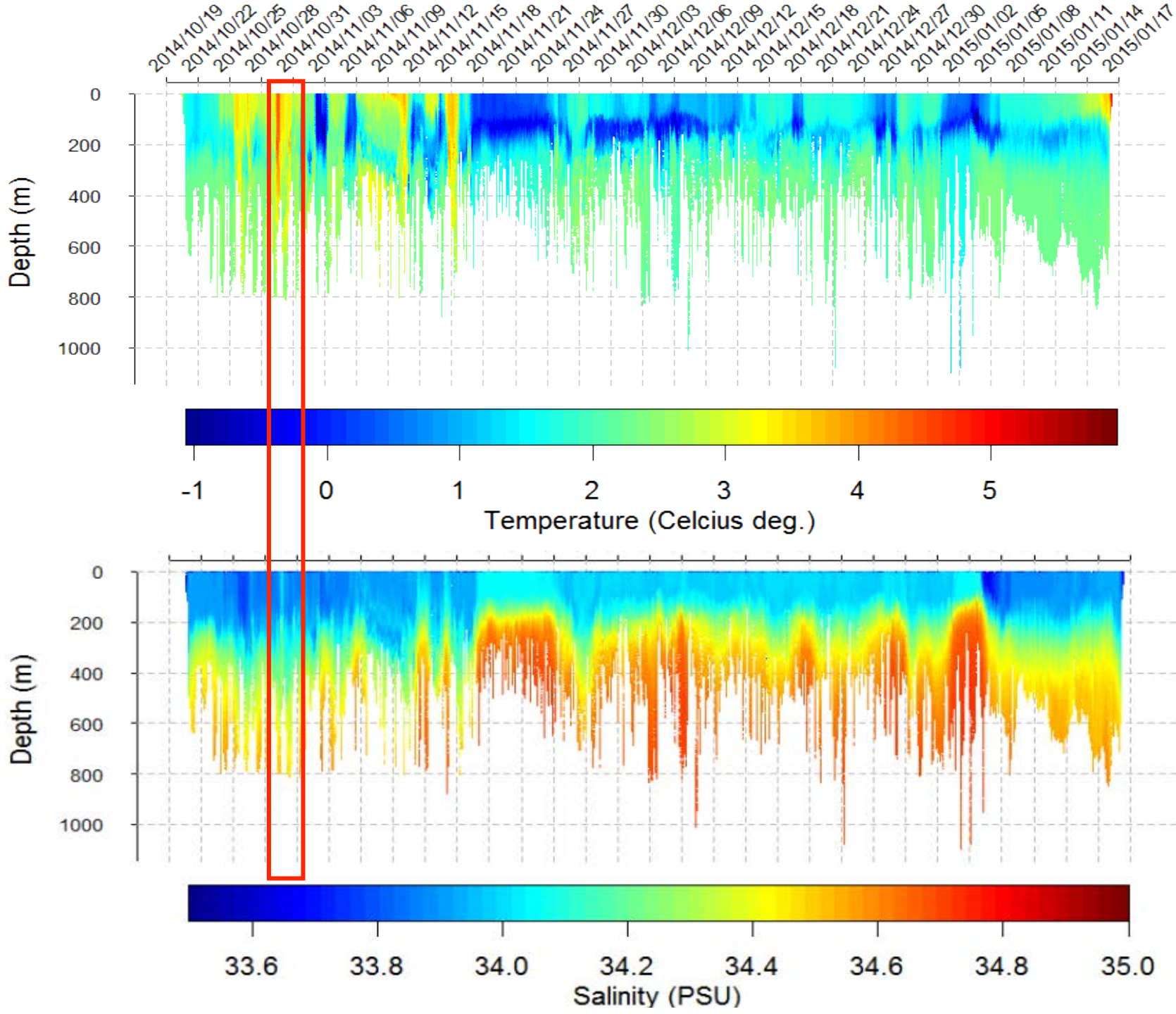
- Depth
- Temperature (0.02°C)
- Salinity (1HZ, 0.03 PSU)
- Fluorescence
- Dissolved oxygen

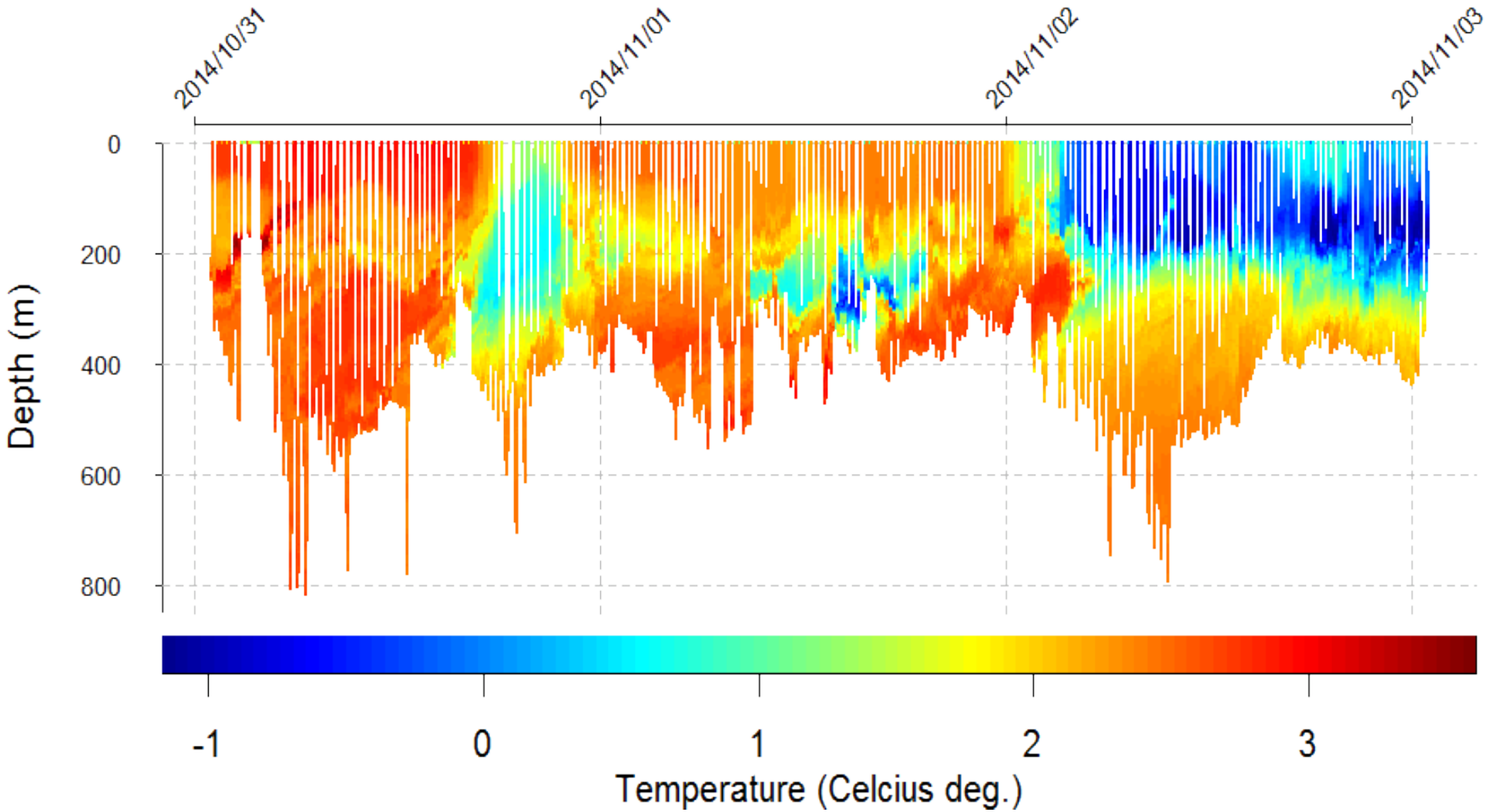
Archived/Differed (the tag need to be recovered)

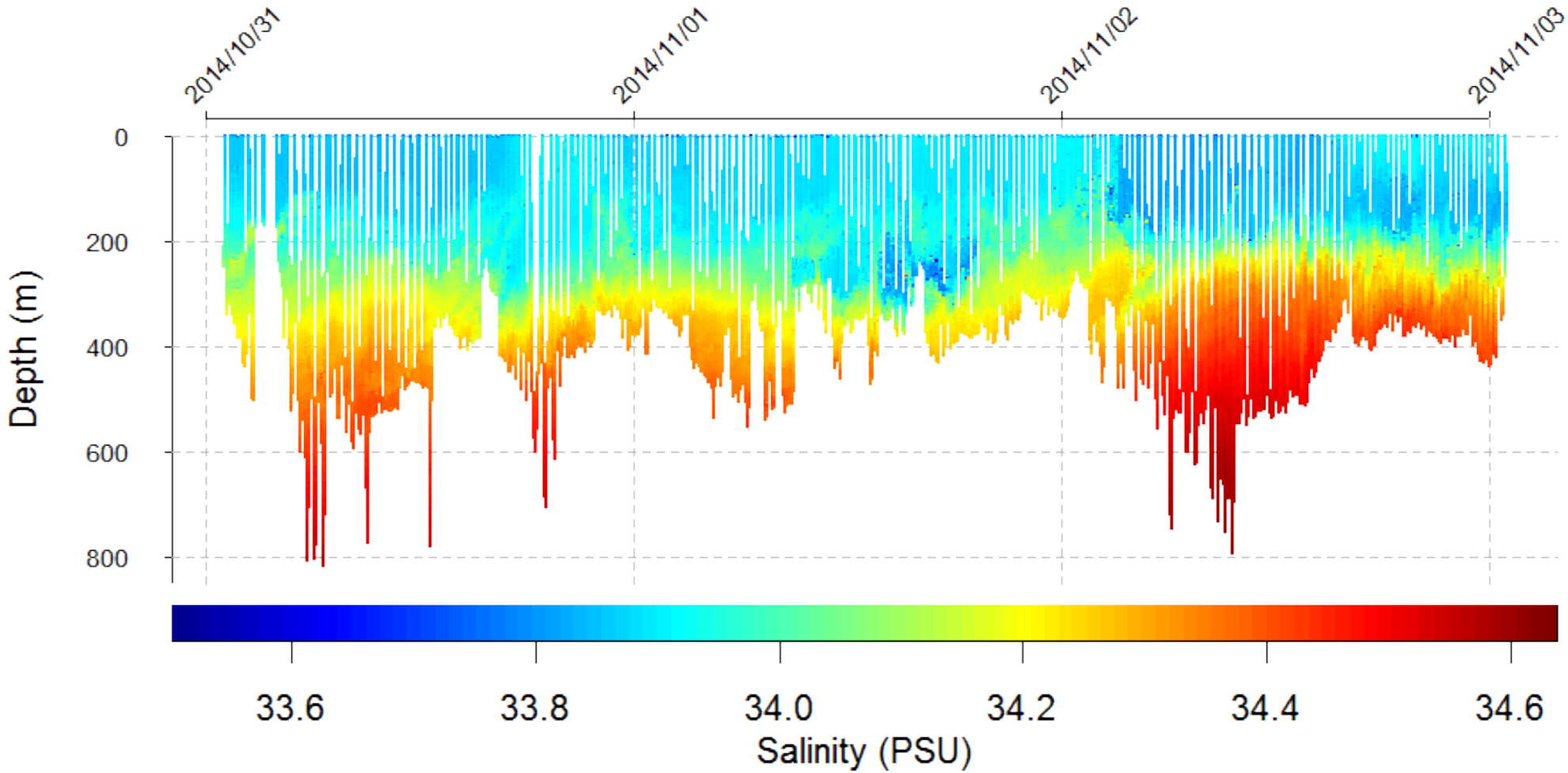
- Depth (0.5 Hz)
- Temperature (0.5 Hz, 0.02°C)
- Salinity (0.5 HZ, 0.03 PSU)
- Fluorescence, (0.5Hz, 4/ profiles per day)
- Dissolved oxygen (0.5 Hz, 4 proFiles per day)
- Light (0.5 Hz)
- Accelerometer (12 Hz)

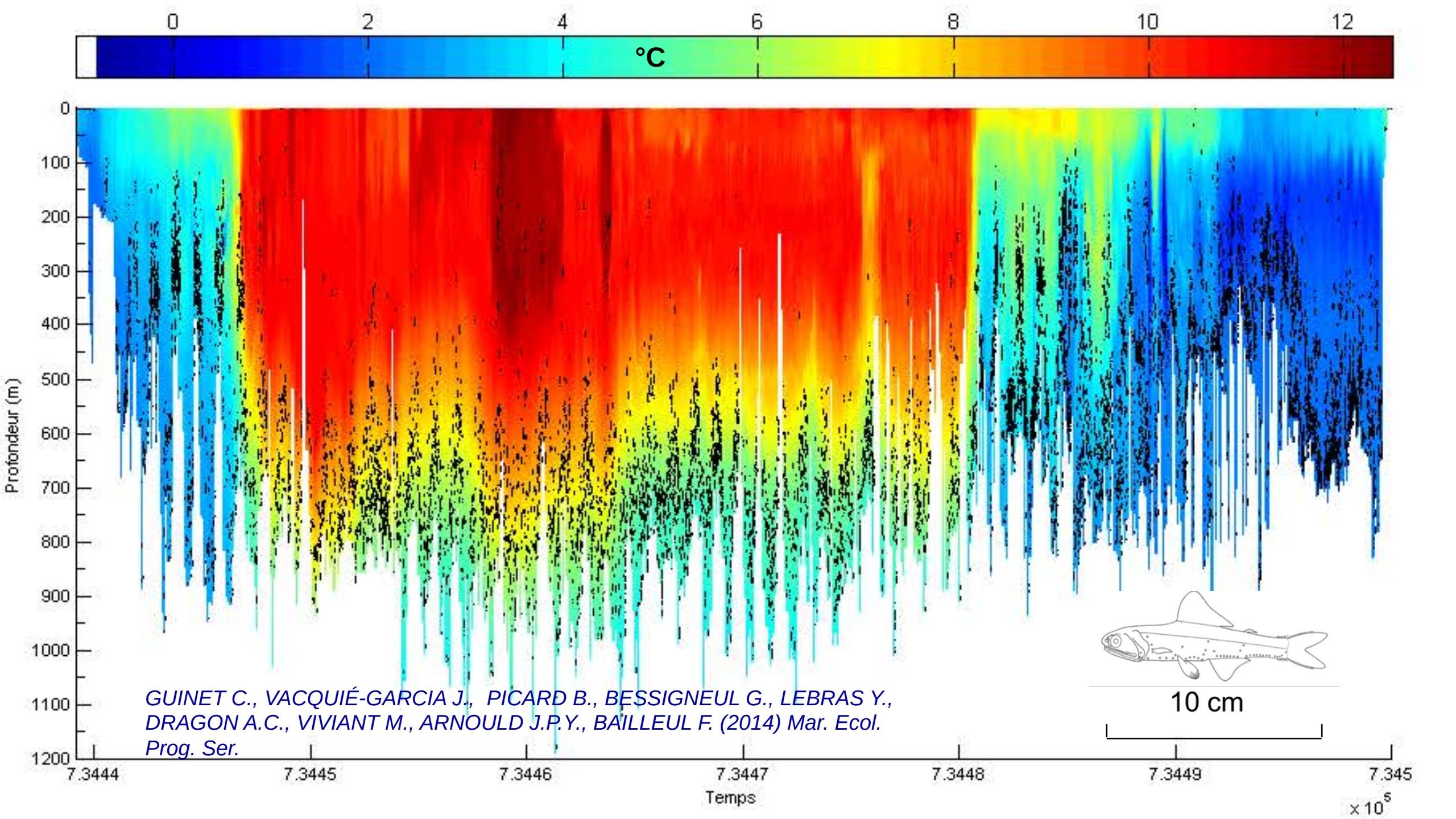

profile nº2519 - day113 - tag:ft22-879-18
LIGHT (normalized by subsurface value)
CHLA adjusted
TEMP adjusted
PSAL adjusted
SEA WATER DENSITY adjusted
PRES (decibar)
LIGHT (dB[ln(umol/m2/s])
CHLA (mg/m3)
TEMP (°C)
PSAL (PSU)
SEA WATER DENSITY (kg.m-3)
DAY
04:33 UTC
MLD
MLD=135m


Trajet du 19 octobre 2014 au 15 janvier 2015
69°E
72°E
75°E
78°E
81°E
84°E
87°E
48°S
51°S
54°S
57°S
GMT Apr 3 08:00

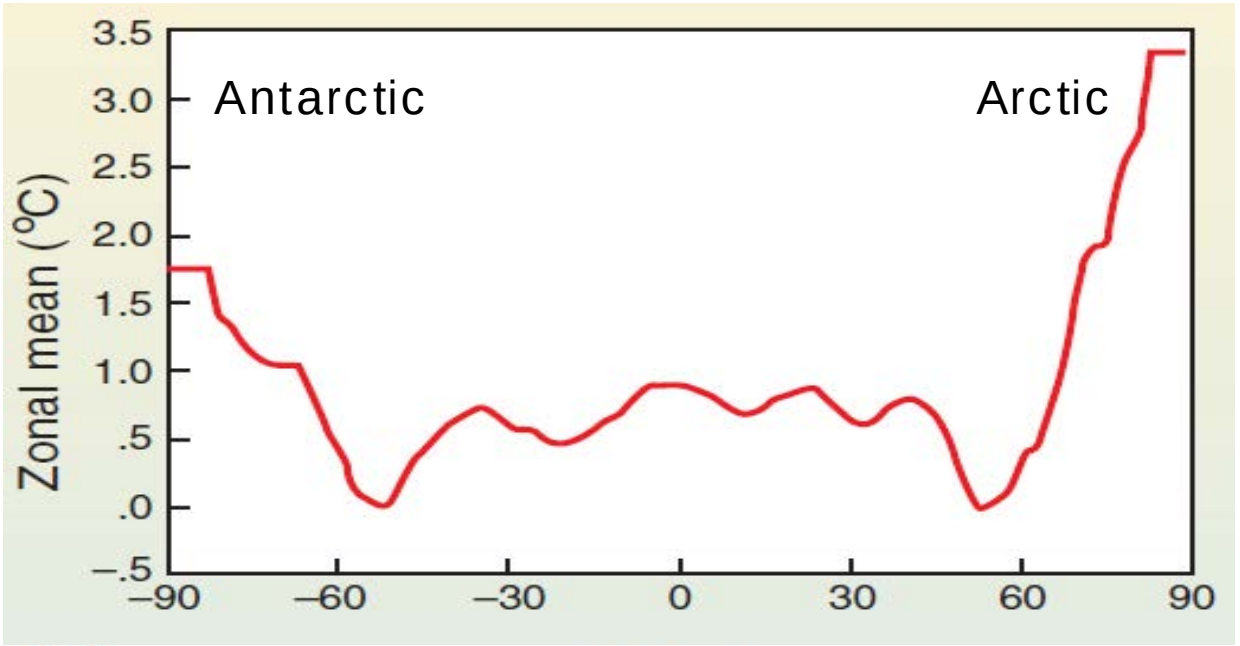

2014/10/19
2014/10/22
2014/10/25
2014/10/28
2014/10/31
2014/11/03
2014/11/06
2014/11/09
2014/11/12
2014/11/15
2014/11/18
2014/11/21
2014/11/24
2014/11/27
2014/11/30
2014/12/03
2014/12/06
2014/12/09
2014/12/12
2014/12/15
2014/12/18
2014/12/21
2014/12/24
2014/12/27
2014/12/30
2015/01/02
2015/01/05
2015/01/08
2015/01/11
2015/01/14
2015/01/17
Depth (m)
0
200
400
600
800
1000
-1
0
1
2
3
4
5
Temperature (Celcius deg.)
Depth (m)
0
200
400
600
800
1000
33.6
33.8
34.0
34.2
34.4
34.6
34.8
35.0
Salinity (PSU)


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


2014/10/31
2014/11/01
2014/11/02
2014/11/03
Depth (m)
0
200
400
600
800
33.6
33.8
34.0
34.2
34.4
34.6
Salinity (PSU)

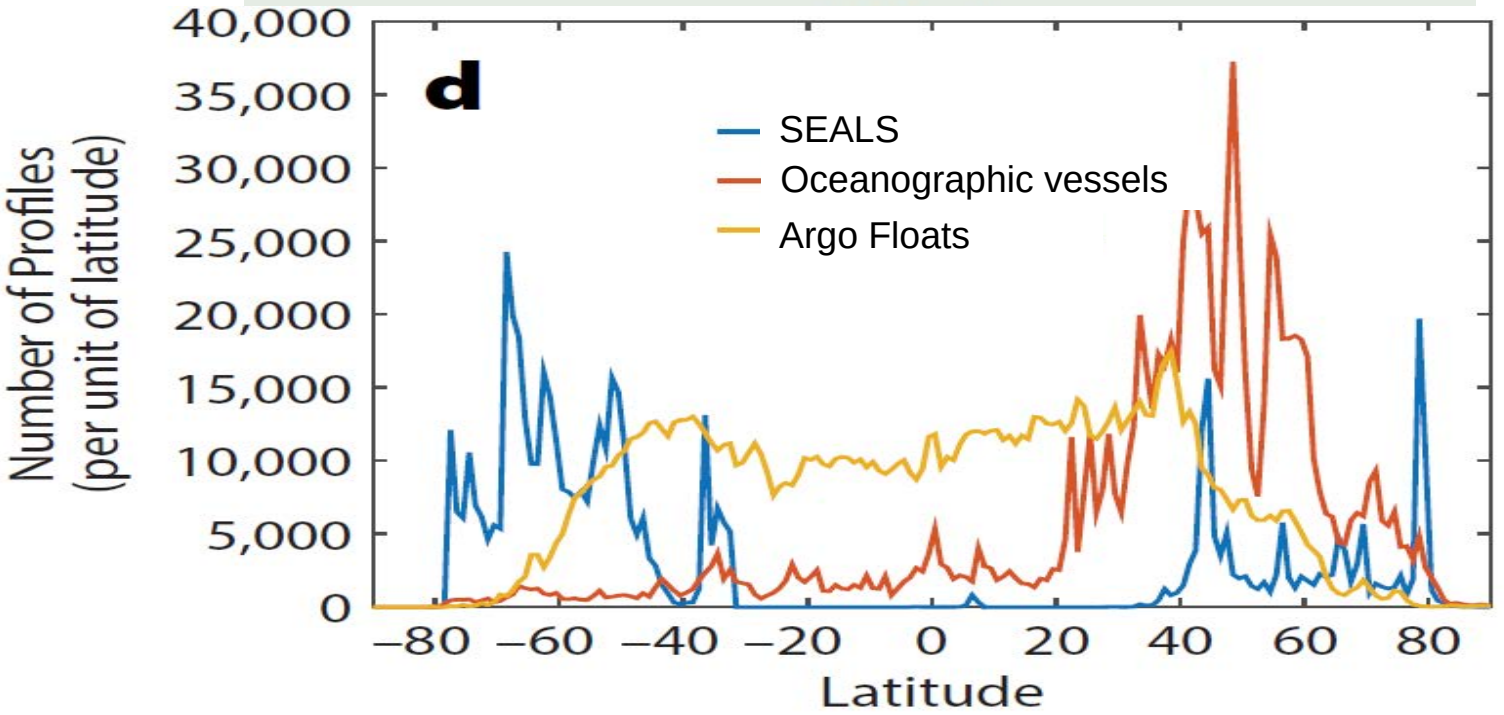


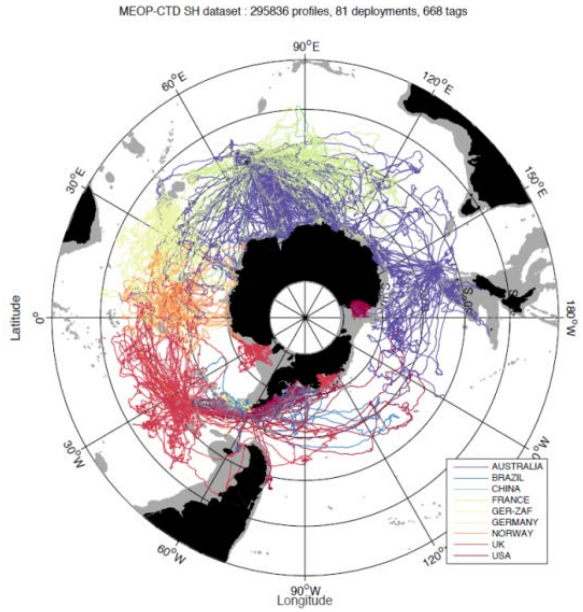
GUINET C., VACQUIÉ-GARCIA J., PICARD B., BESSIGNEUL G., LEBRAS Y., DRAGON A.C., VIVIANT M., ARNOULD J.P.Y., BAILLEUL F. (2014) Mar. Ecol. Prog. Ser.



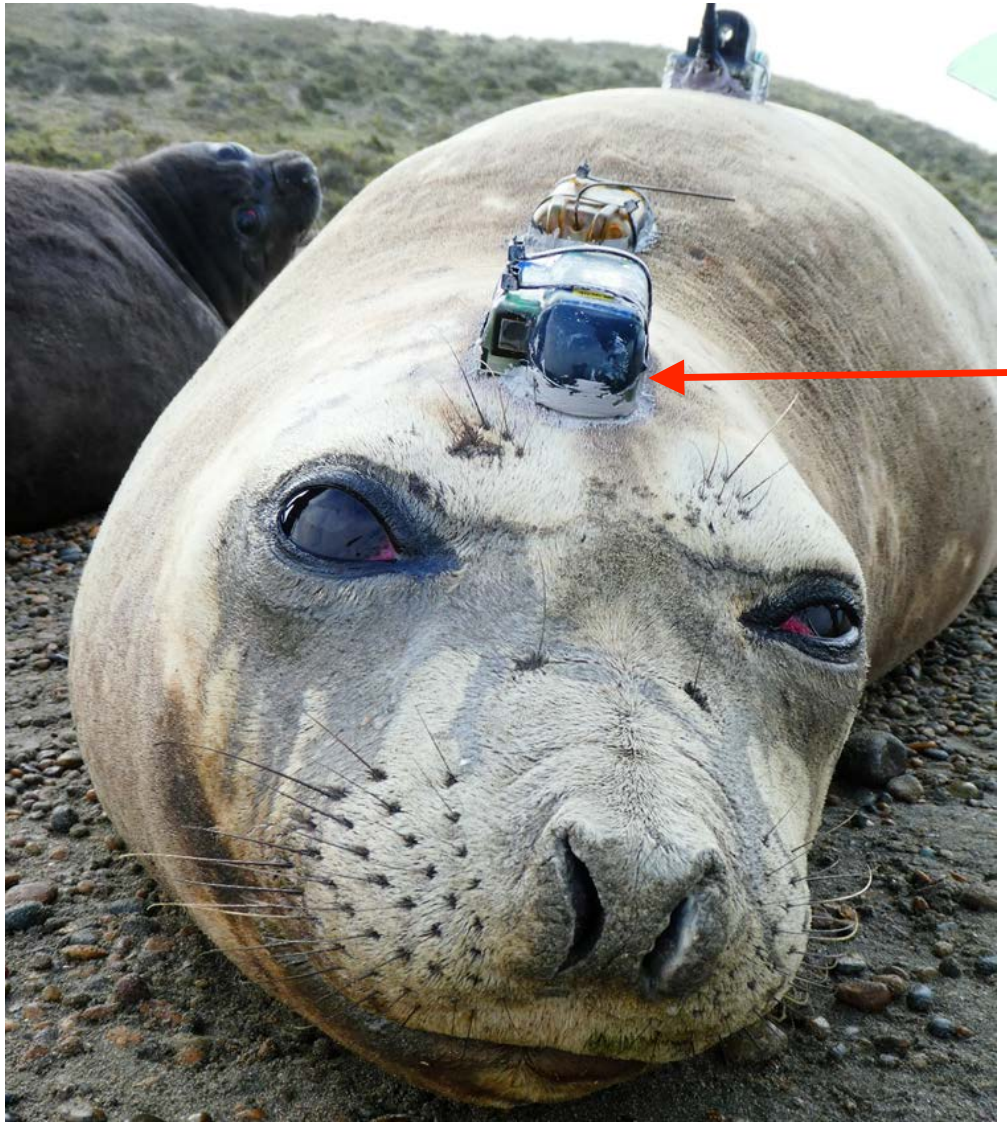
98 % of the profiles within antarctic sea-ice

www.meop.net





Sea-state (waves) and wind
(CFOSAT-2018)



Hydrophone

Accelerometer,
Magnetometer,

Pressure sensor,
GPS,
Light sensor,
Temperature sensor

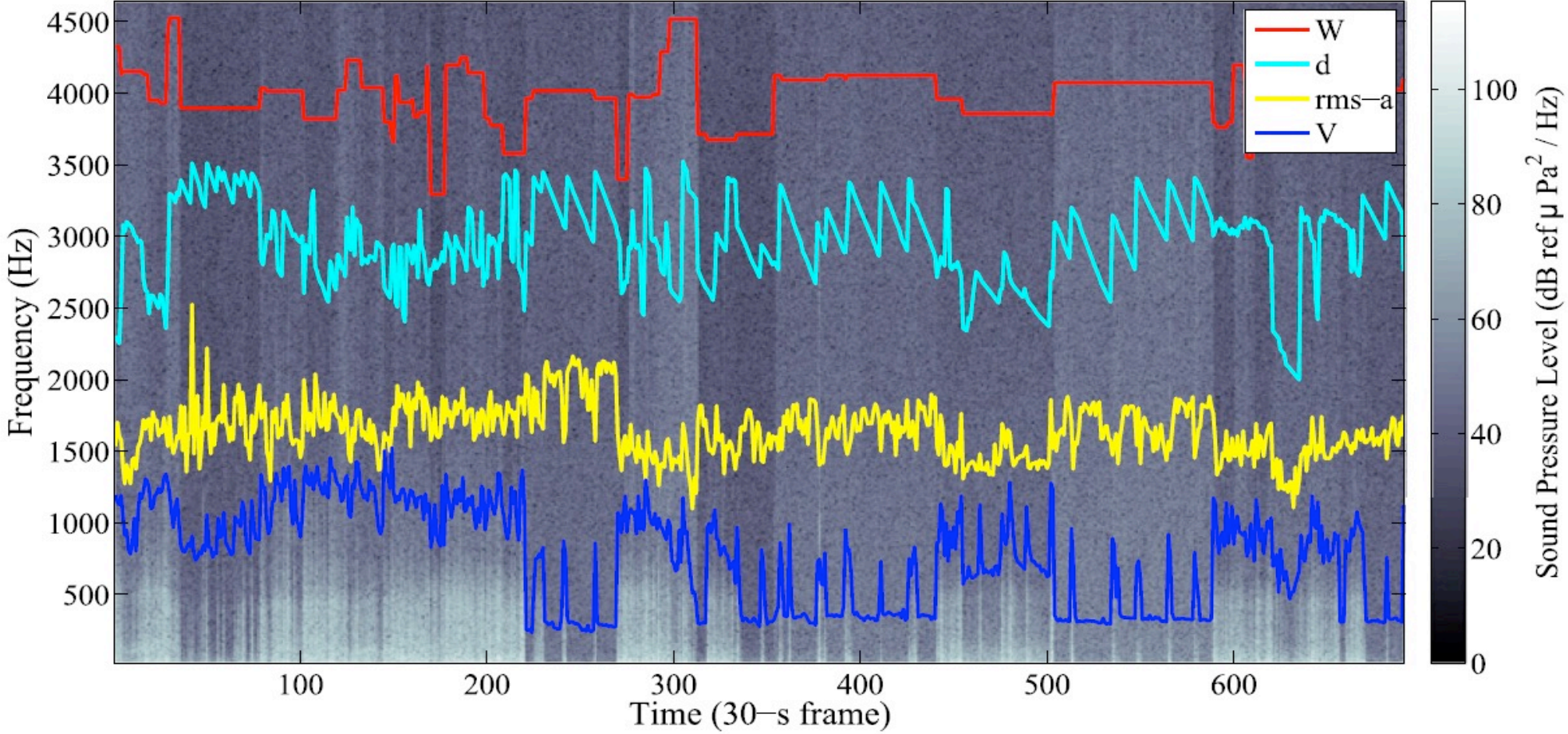
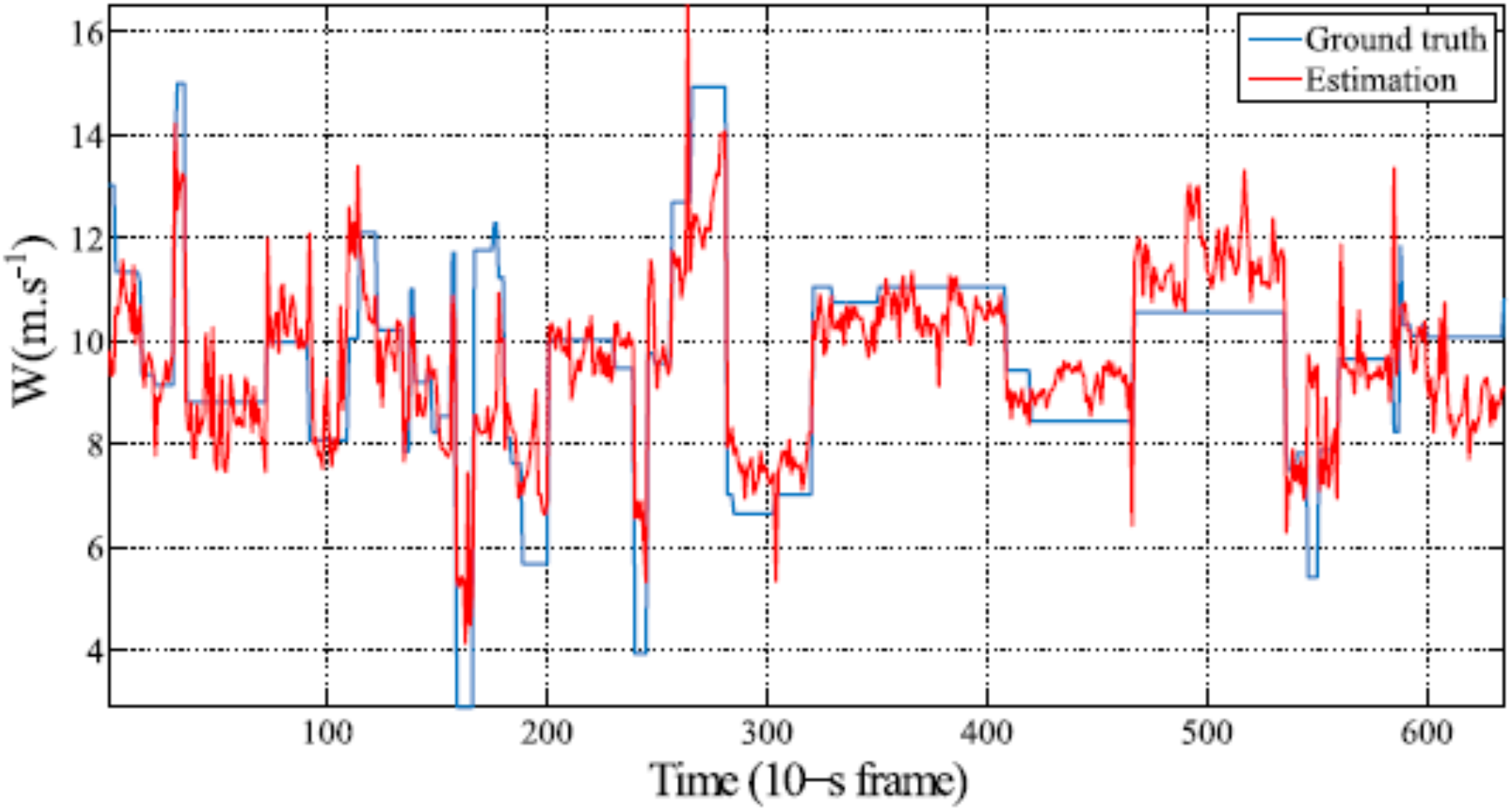


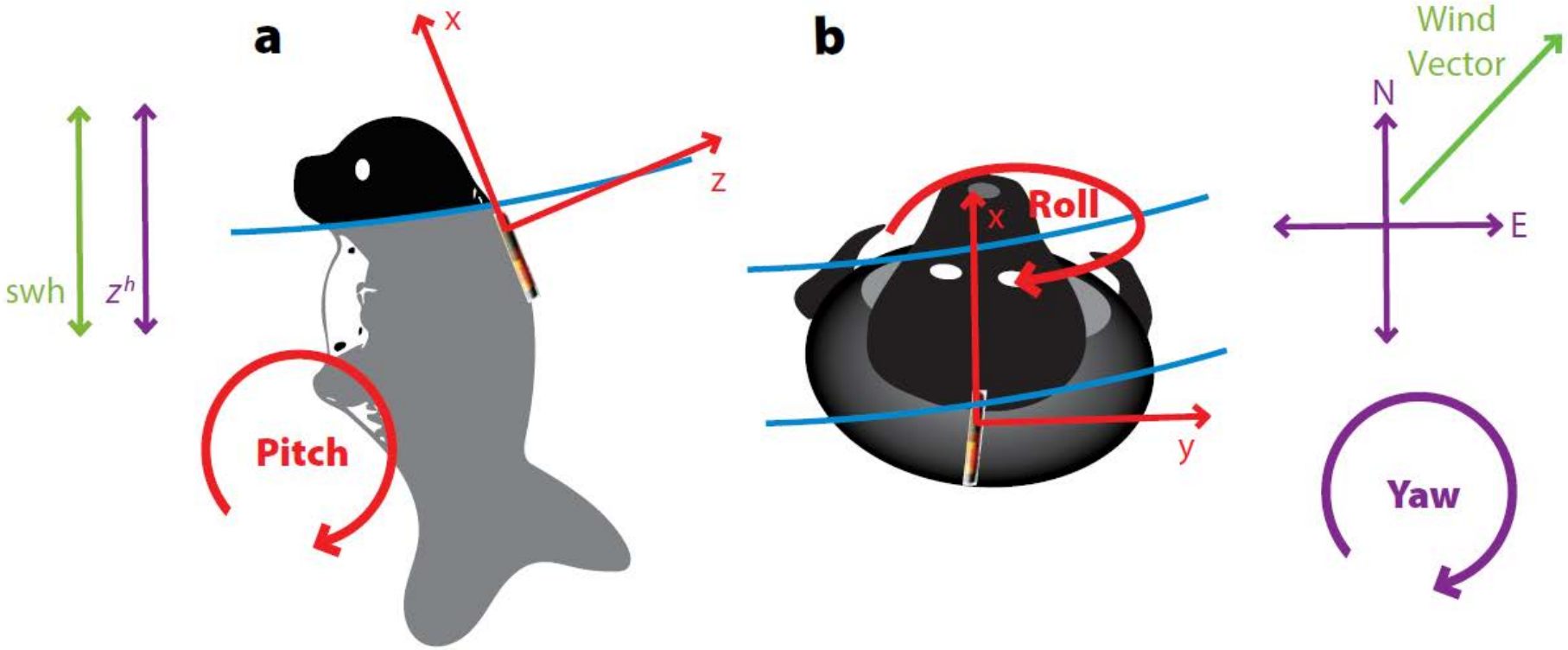
FIG. 3. Long-term spectrogram averaged over four acoustic recordings (i.e., a total of 16 h of recordings from four different days) from SES A626019. It was generated using 2048-point FFTs, Hamming windows, and no overlap, and averaged every 30 s. The four variables V, rms $- a$, d, and W are superimposed onto the spectrogram with relative linear scales ranging from 0.3 to 2.7 m s^{-1}, 0.2 to 10 m s^{-2}, -150 to 600 m, and 4 to 18 m s^{-1}, respectively.

CAZAU D., BONNEL J., JOUMA'A J., LE BRAS Y., GUINET C. (2017) Measuring the marine soundscape of the Indian Ocean with Southern Elephant Seals used as acoustic gliders of opportunity. Journal of Atmospheric and Oceanic Technology. 34:207–223. DOI: 10.1175/JTECH-D-16-0124.1

In-situ estimations from the noise level recorded by SES when diving

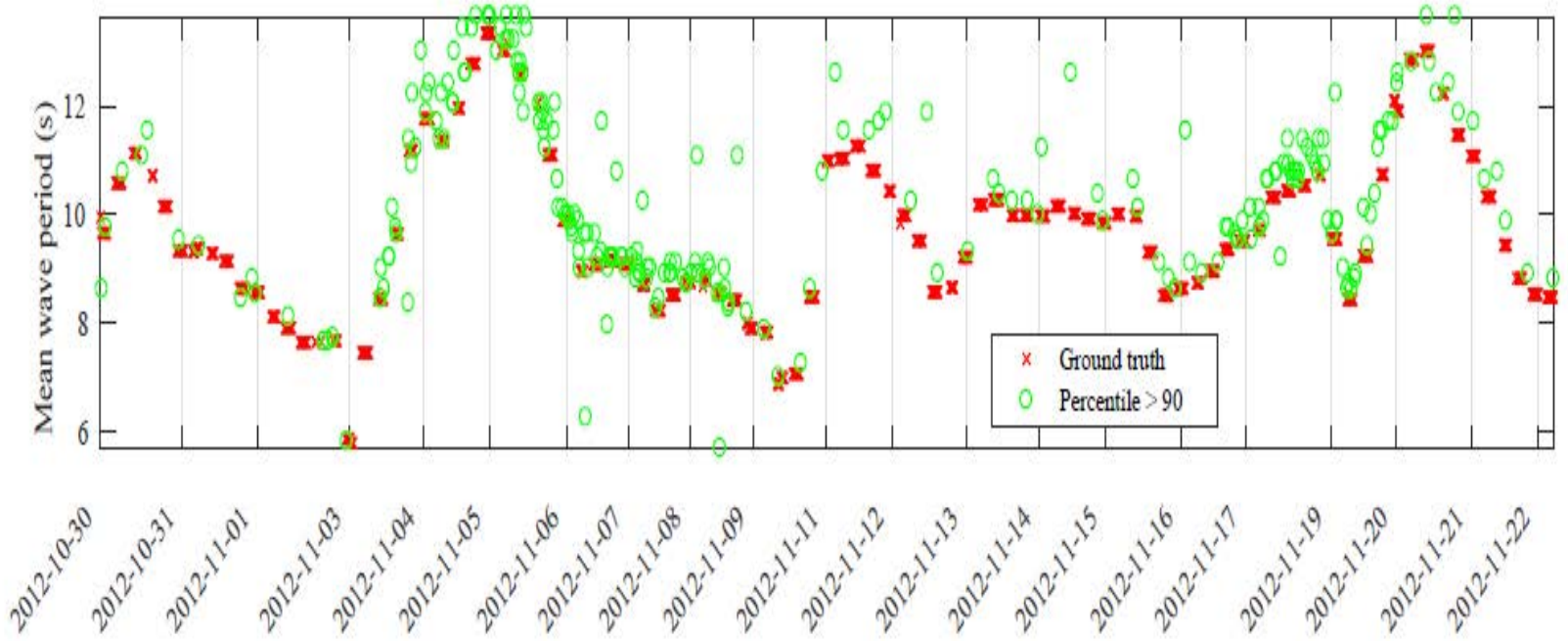


CAZAU D., BONNEL J., JOUMA'A J., LE BRAS Y., GUINET C. (2017) Measuring the marine soundscape of the Indian Ocean with Southern Elephant Seals used as acoustic gliders of opportunity. Journal of Atmospheric and Oceanic Technology. 34:207–223. DOI: 10.1175/JTECH-D-16-0124.1

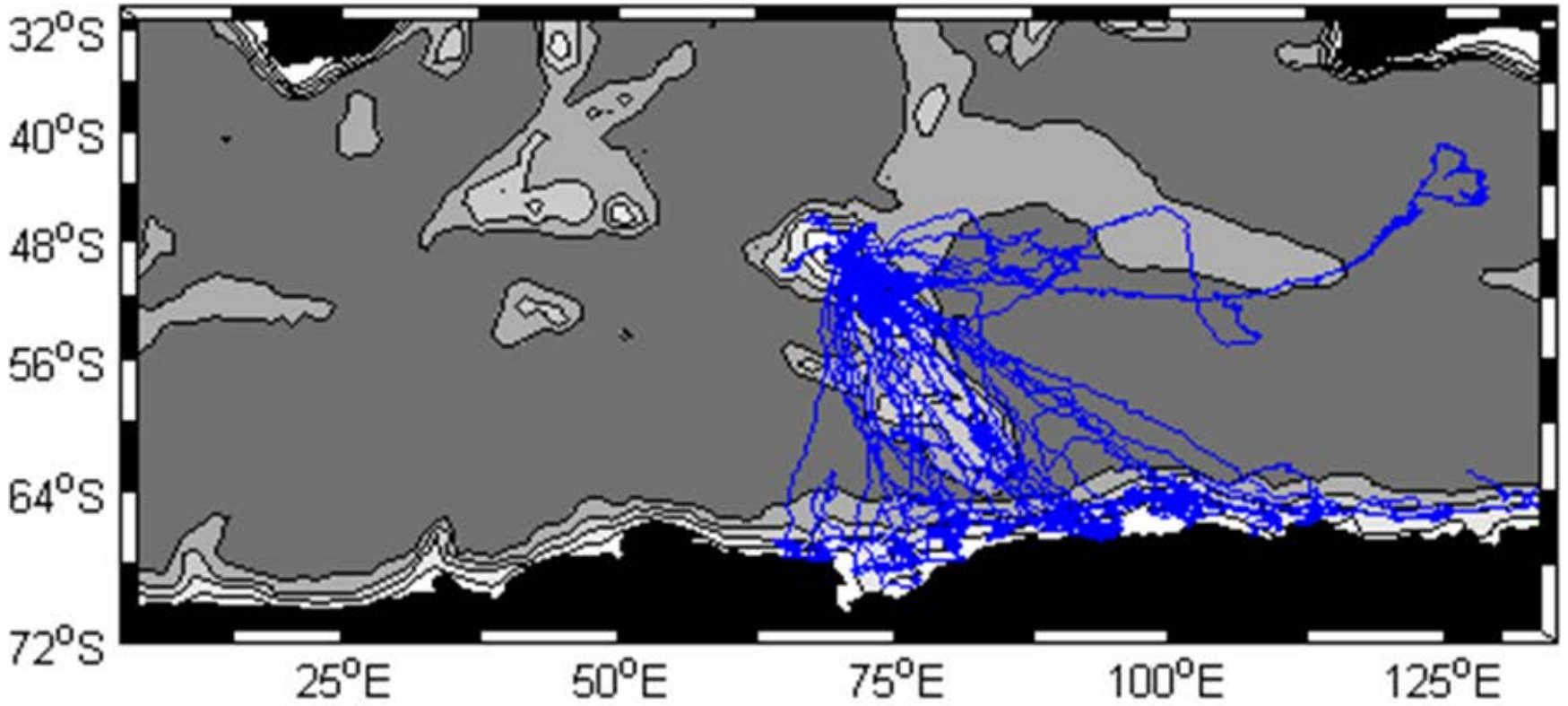


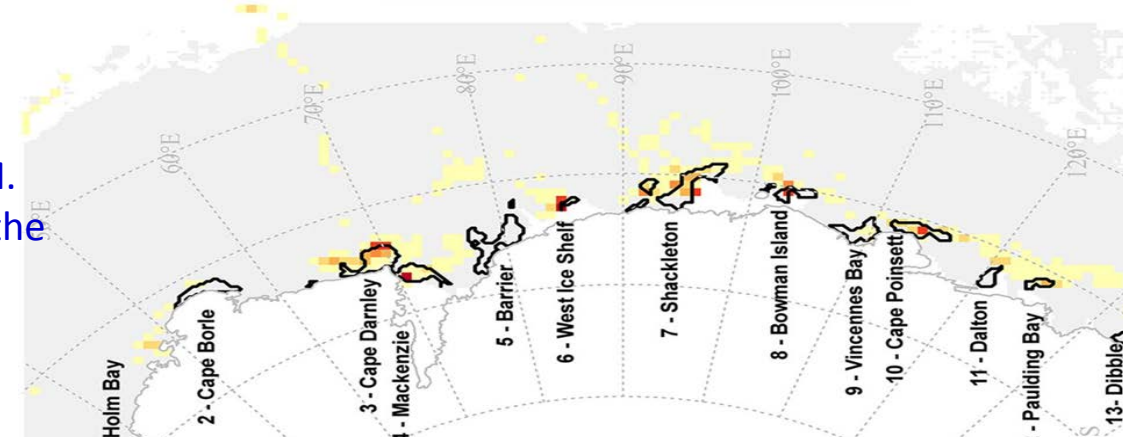
CAZAU D., PRADALIER C., BONNEL J., GUINET C., (2017).Do Southern Elephant Seals buoy like meteorological buoys ? Oceanography 30(2):140–149, https://doi.org/10.5670/oceanog.2017.236.

Waves frequency and amplitudes (acceleration)



CAZAU D., BONNEL J., JOUMA'A J., LE BRAS Y., GUINET C. (2017) Measuring the marine soundscape of the Indian Ocean with Southern Elephant Seals used as acoustic gliders of opportunity. Journal of Atmospheric and Oceanic Technology. DOI: 10.1175/JTECH-D-16-0124.1

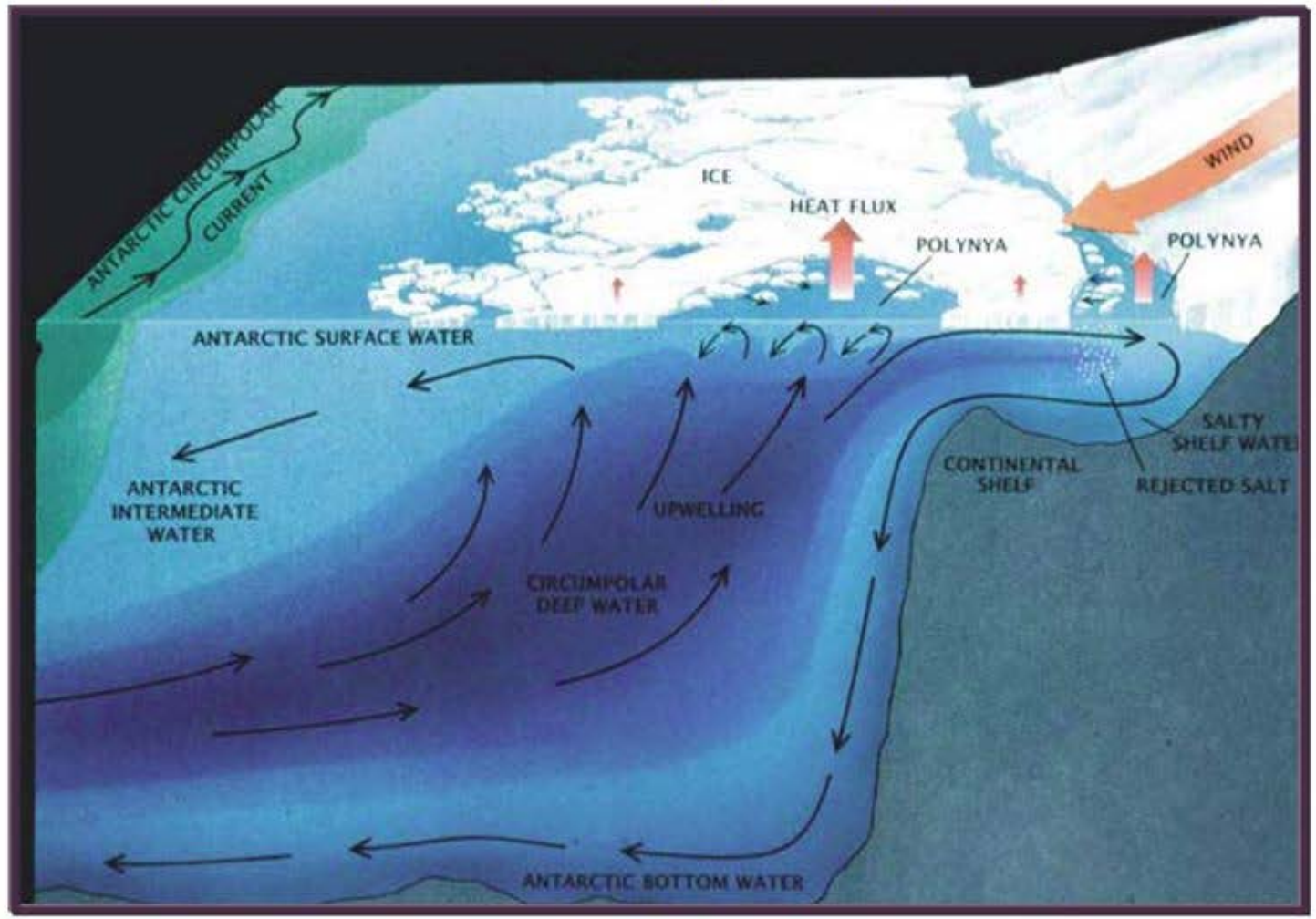




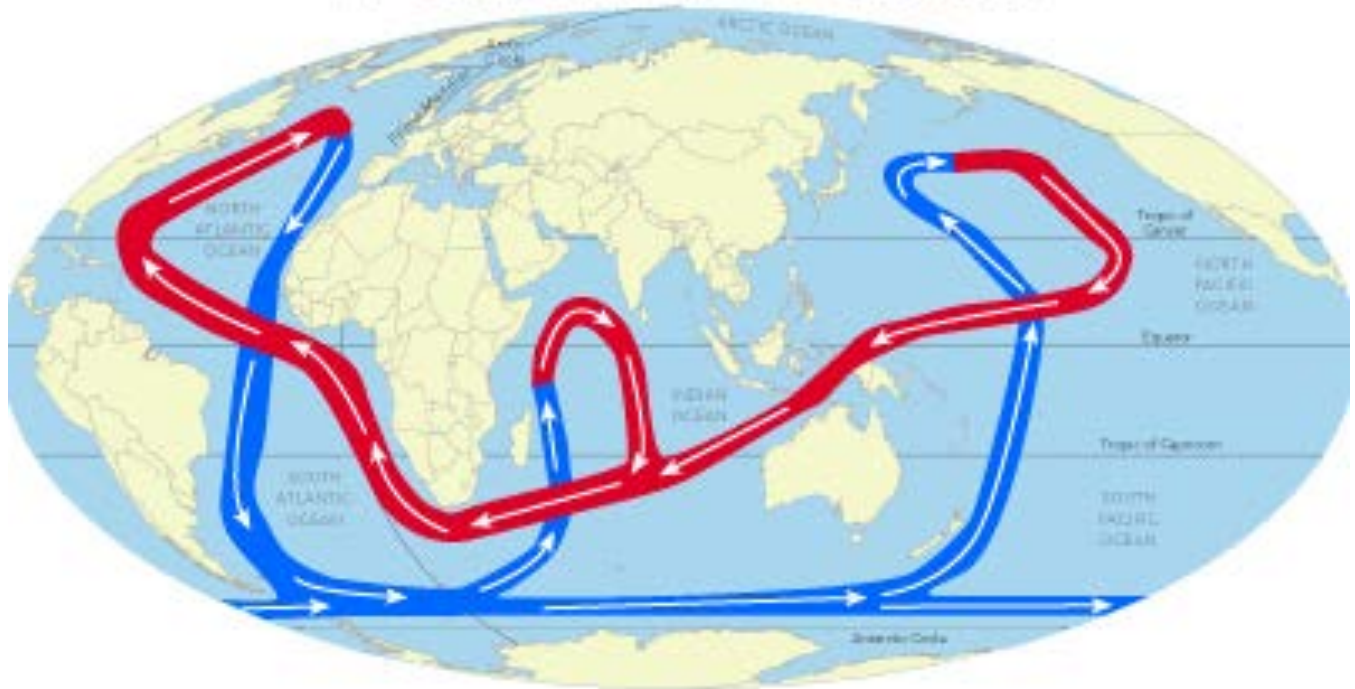
LABROUSSE, S., J. B. SALLÉE, A. D. FRASER, R. MASSOM, P. REID, M. SUMNER, C. GUINET, R. HARCOURT, C. R. MCMAHON, F. BAILLEUL, M. HINDELL AND J. B. CHARRASSIN (2017). Under the sea ice: Exploring the relationship between sea ice and the foraging behaviour of southern elephant seals in East Antarctica. Progress in Oceanography 156: 17-40.doi: 10.1016/j.pocean.2017.05.014

Polynya ?

Antarctic Bottom Water (AABW) Formation



70. Ocean Thermohaline Circulation



Thermohaline (THC) Currents or the Global Ocean Conveyor Belt

Deep flow: Cool and salty water is more dense and sinks to the bottom of the oceans.

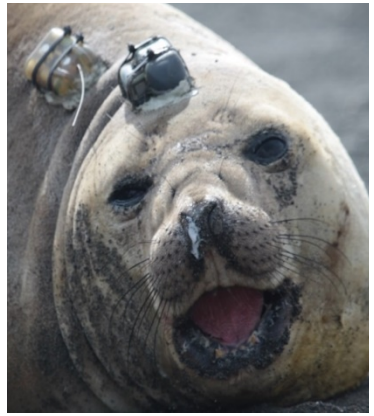
Shallow flow: Warm water is less dense and rises to the surface of the oceans.

One cycle of the conveyor belt takes about 1,000 years, but shifts in the THC's conveyor belt can cause major changes in climate over relatively short timescales (10-20 years).

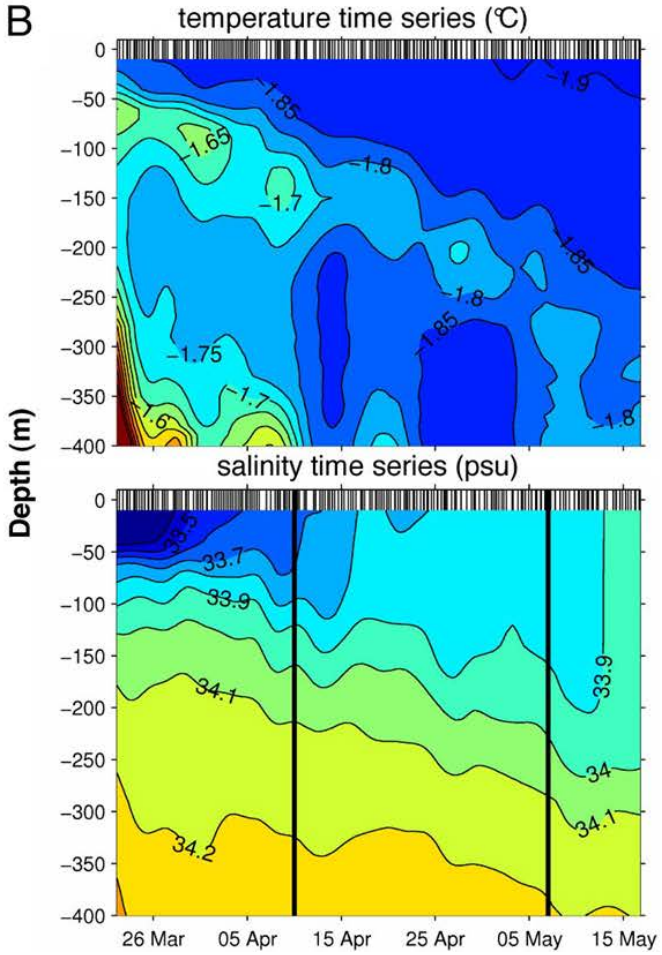
N
W E
S

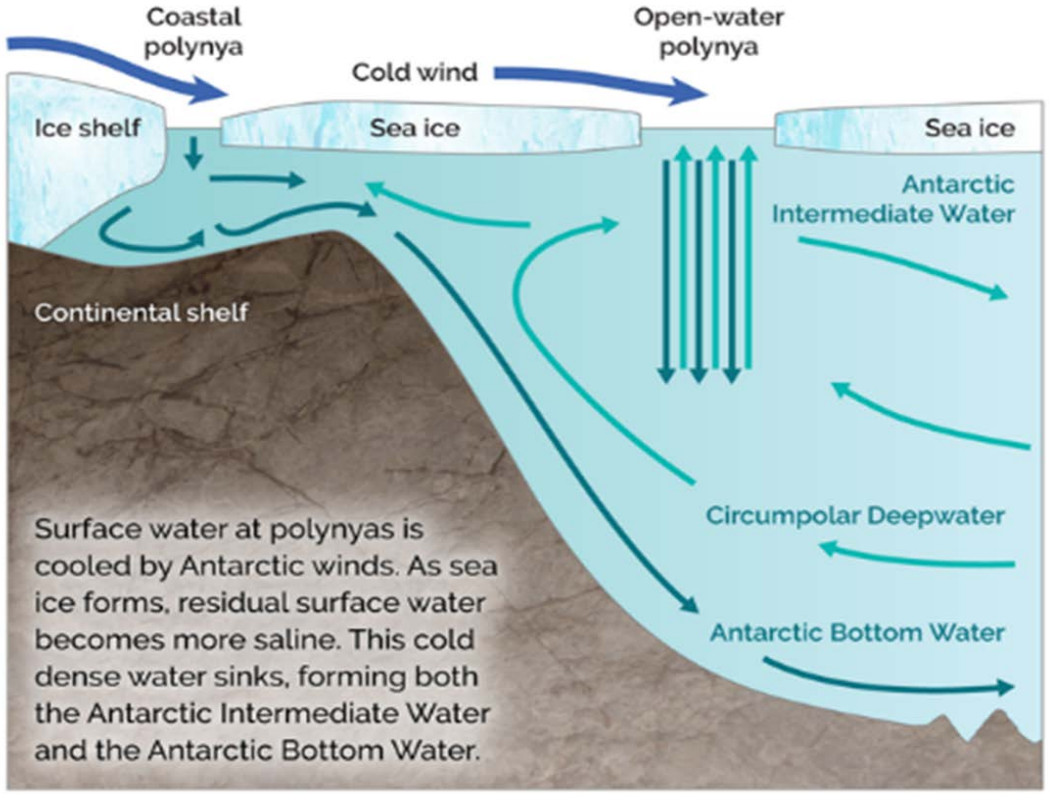
0 2,500 5,000
Miles

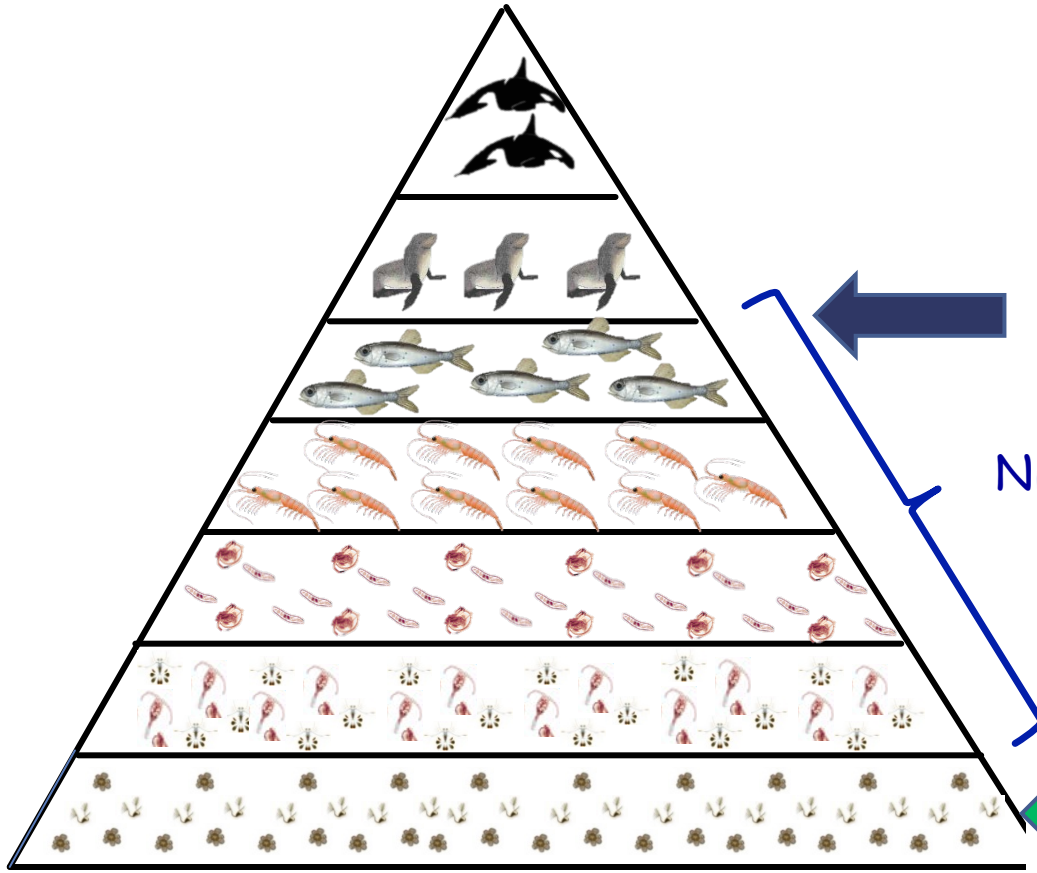
Data courtesy of the National Ocean Service (NOS), National Oceanographic and Atmospheric Administration (NOAA), 2011



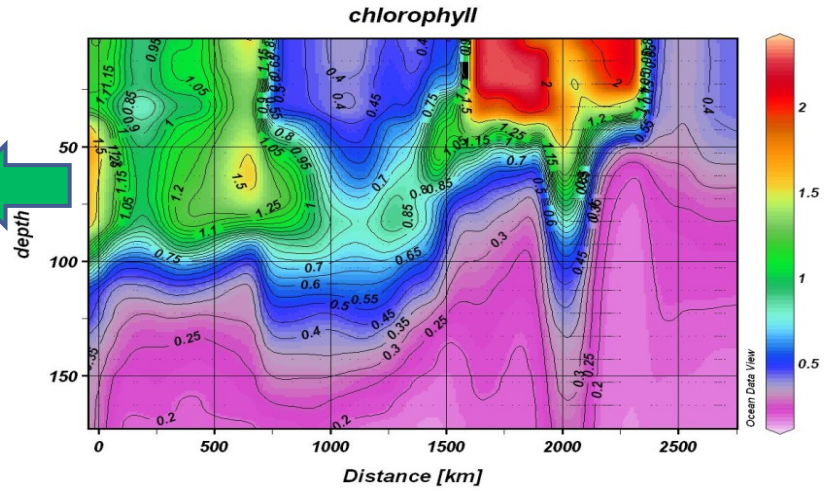
B

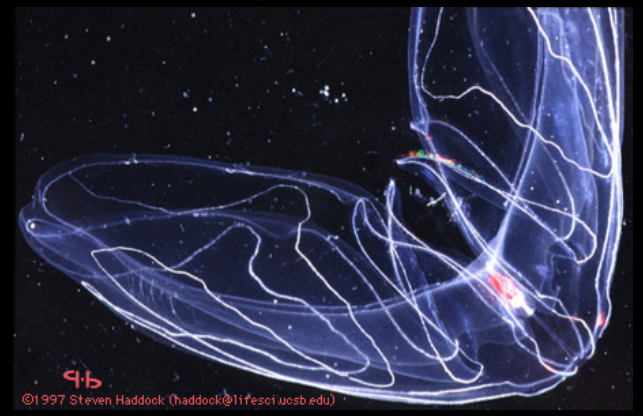

temperature time series (℃)
salinity time series (psu)
Depth (m)
0
−50
−100
−150
−200
−250
−300
−350
−400
−1.9
−1.85
−1.65
−1.8
−1.7
−1.75
−1.6
33.5
33.7
33.9
34.1
34.2
34
26 Mar
05 Apr
15 Apr
25 Apr
05 May
15 May

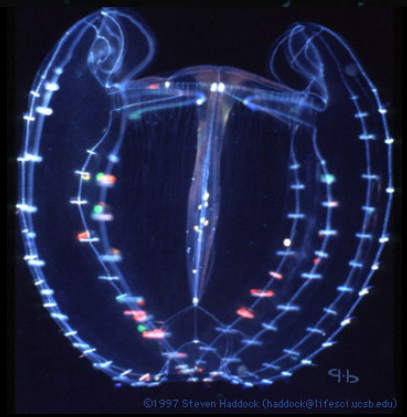

Coastal polynya
Cold wind
Open-water polynya
Ice shelf
Sea ice
Sea ice
Antarctic Intermediate Water
Continental shelf
Circumpolar Deepwater
Antarctic Bottom Water
Surface water at polynyas is cooled by Antarctic winds. As sea ice forms, residual surface water becomes more saline. This cold dense water sinks, forming both the Antarctic Intermediate Water and the Antarctic Bottom Water.



Niveaux intermédiaires?





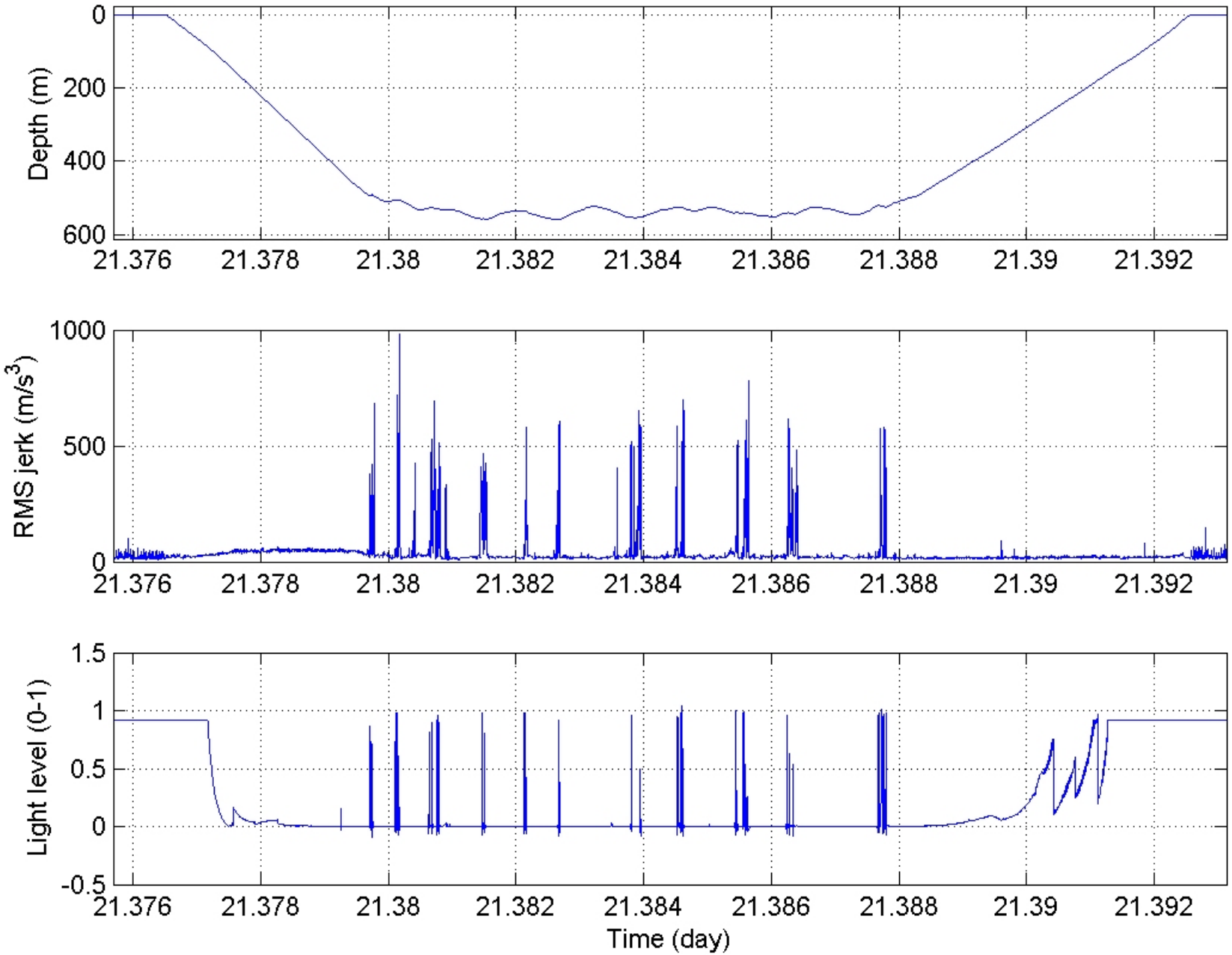


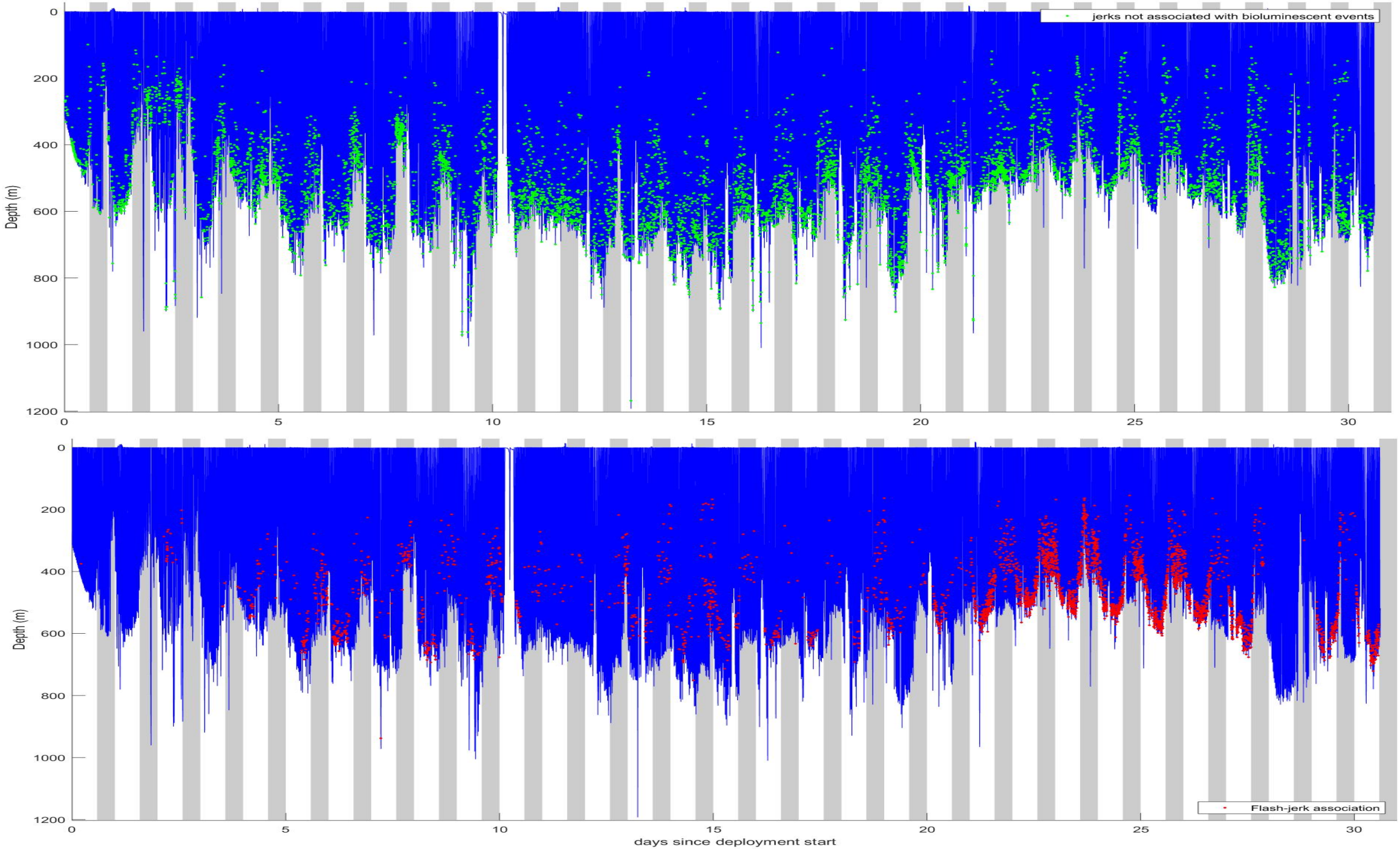
VACQUIÉ-GARCIA J., ROYER F., DRAGON A.C., VIVIANT M., BAILLEUL F., GUINET C. 2012. Foraging in the darkness of the Southern Ocean: influence of Bioluminescence on a deep diving predator. Plos One

Developping new biollogging techniques to observe and investigate intermediate trophic levels

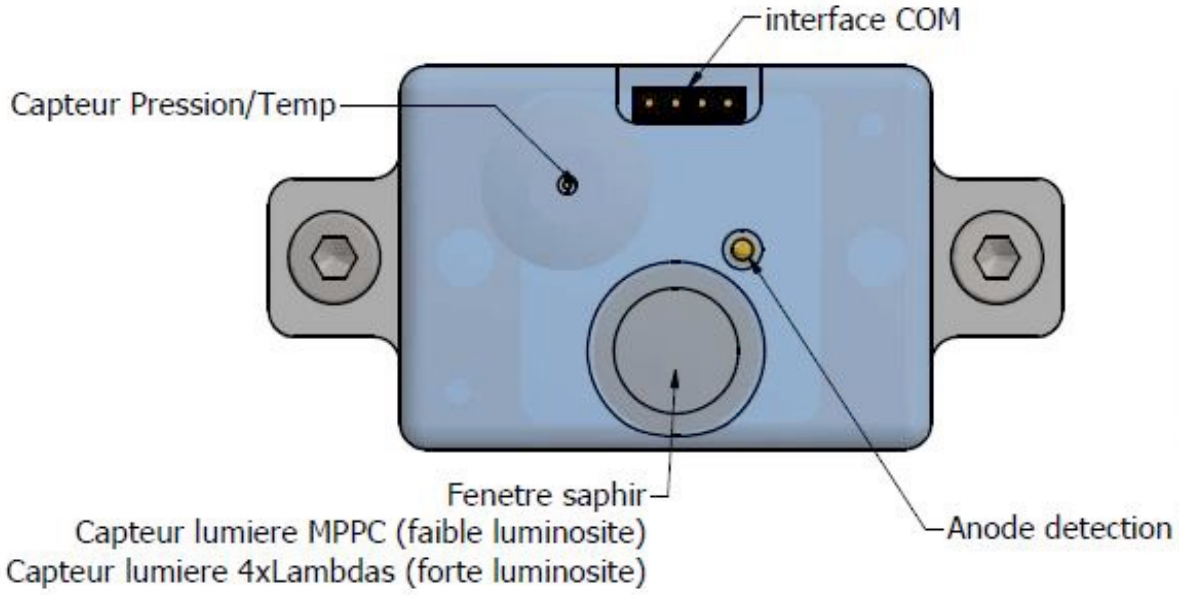
(Collaboration M. Johnson & P. Goulet Sea Mammal Research Unit):

High sensitivity-High frequency 50 hZ sampling Light sensor

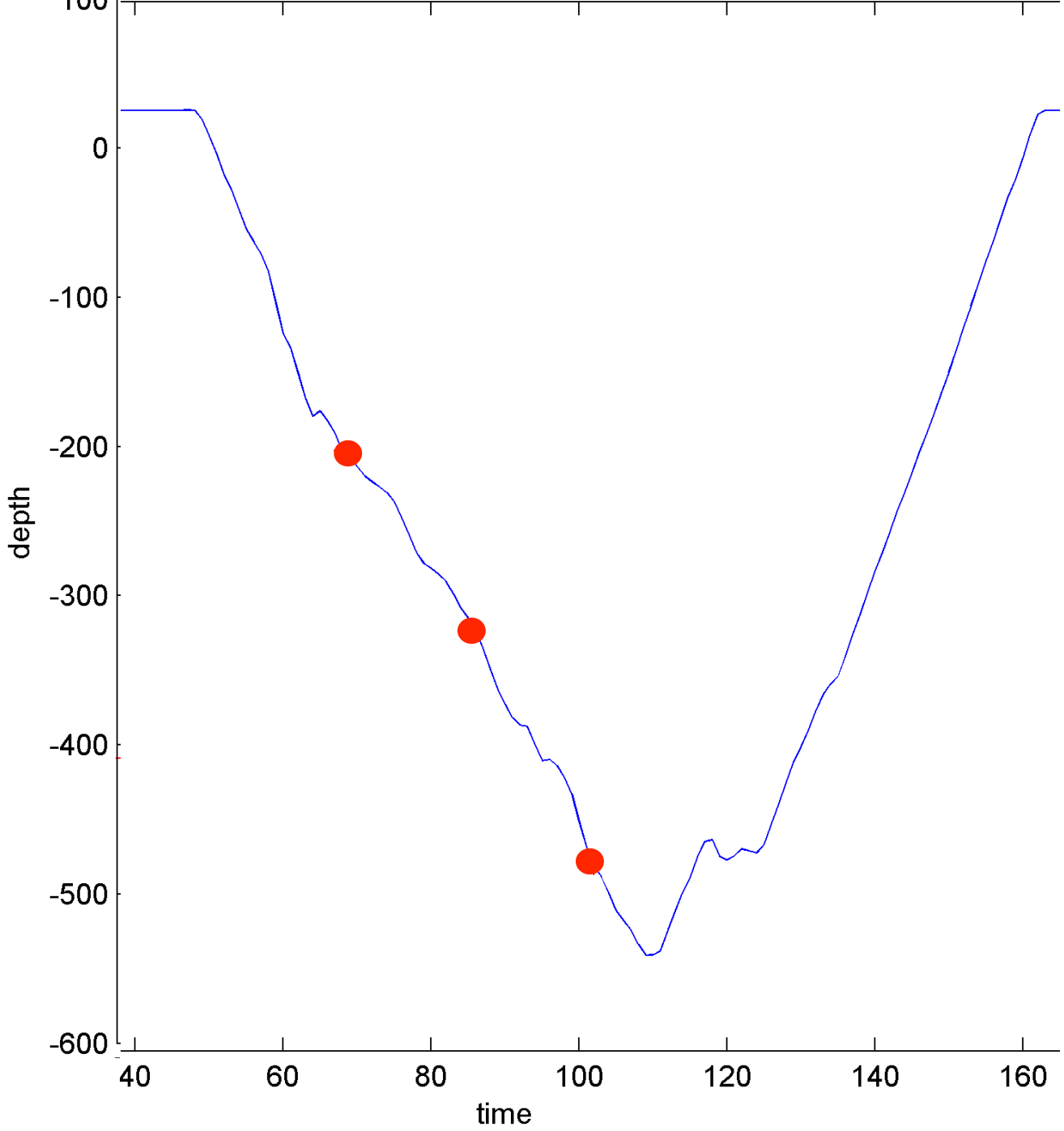

Depth (m)
0
200
400
600
RMS jerk (m/s^3)
1000
500
0
Light level (0-1)
1.5
1
0.5
0
-0.5
21.376
21.378
21.38
21.382
21.384
21.386
21.388
21.39
21.392
Time (day)

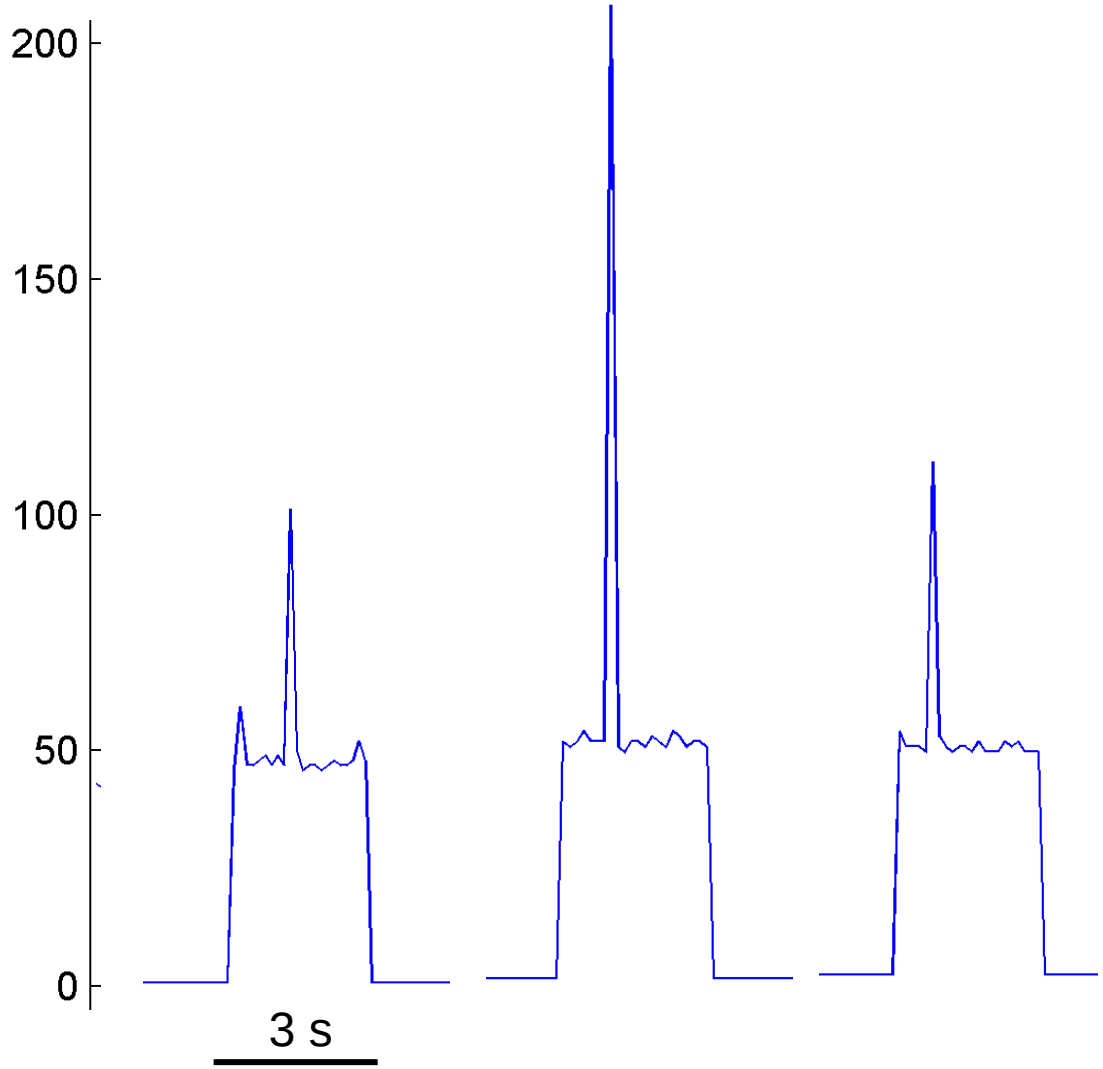

jerks not associated with bioluminescent events
Depth (m)
0
200
400
600
800
1000
1200
0
5
10
15
20
25
30
Flash-jerk association
days since deployment start

Implémentation d’un nouveau photomultiplicateur pour caractériser l’intensité et la cinétique des signaux de bioluminescence. (**Voir Poster AEI 4.5 Severine Martini et al.)**

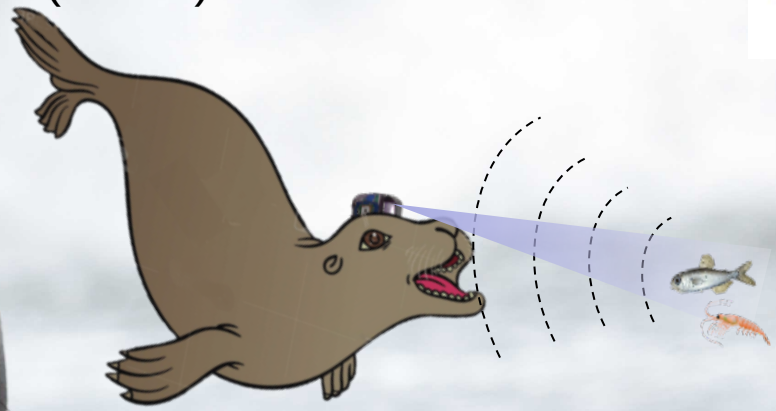


Lumière échantillonnée à 10hz


100
0
-100
-200
-300
-400
-500
-600
depth
40
60
80
100
120
140
160
time


200
150
100
50
0
3 s

Active µ-sonar: collaboration with M. Johnson & P. Goulet, Sea Mammal Research Unit):
Tiphaine Jeanniard du Dot (CEBC)



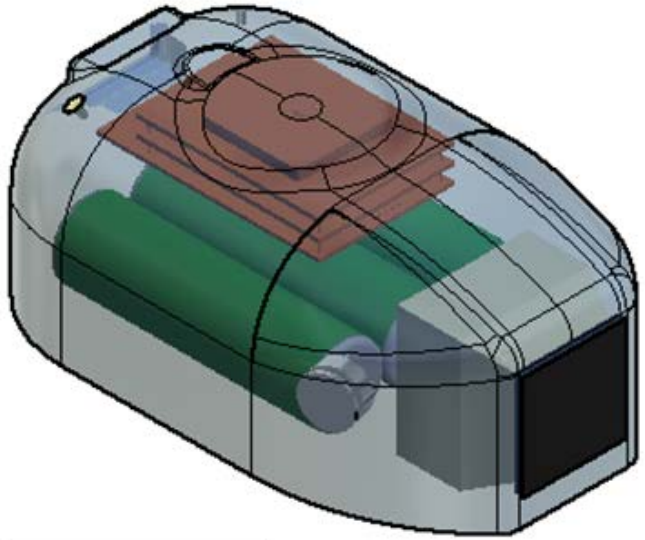
SenSe SENTINELS OF THE SEA ICE

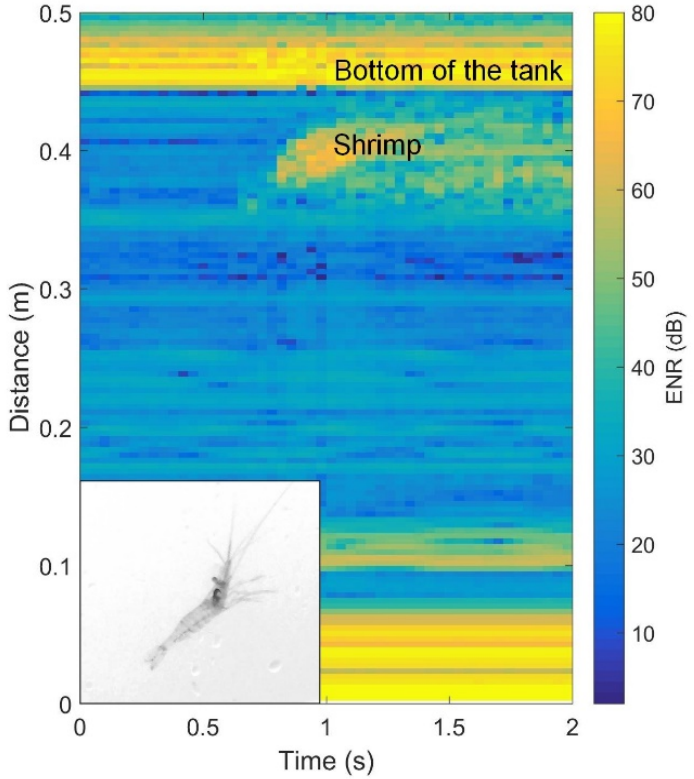
FONDATION BNP PARIBAS

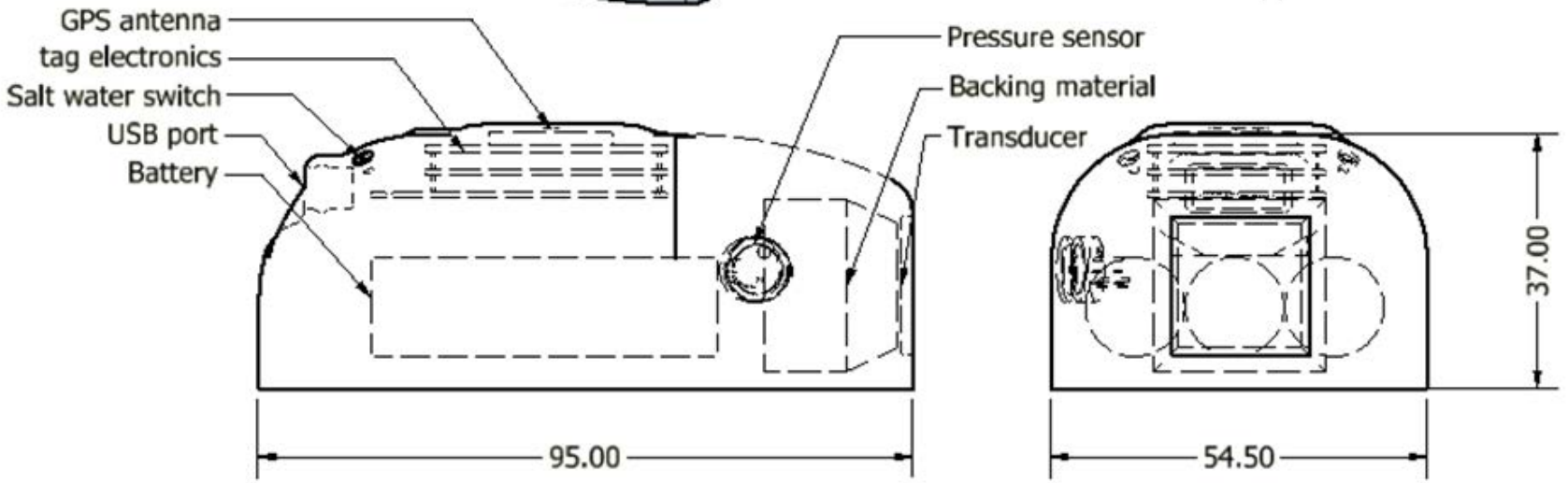
Sous l'égide de la Fondation de France

cnes

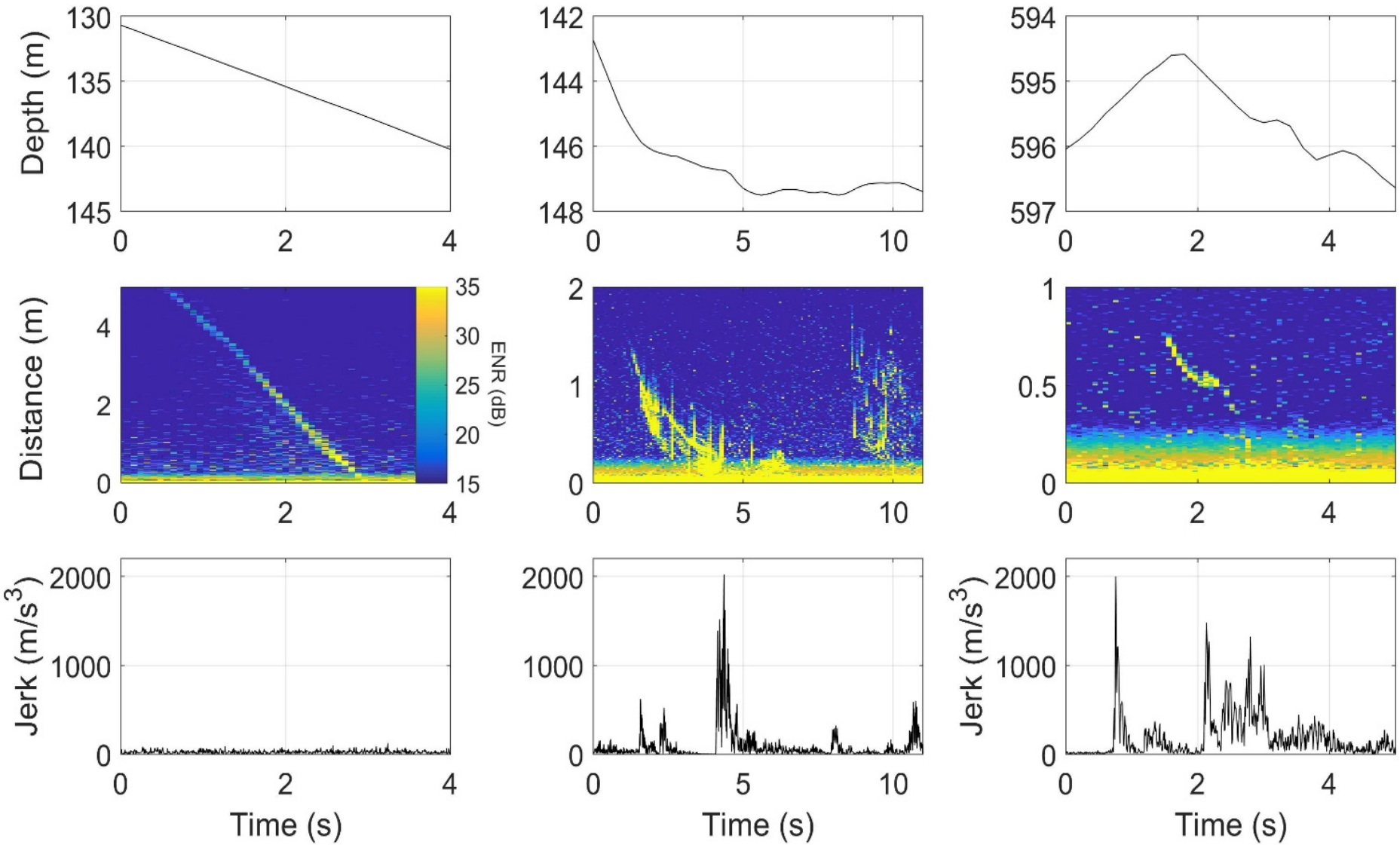
CENTRE NATIONAL D'ÉTUDES SPATIALES

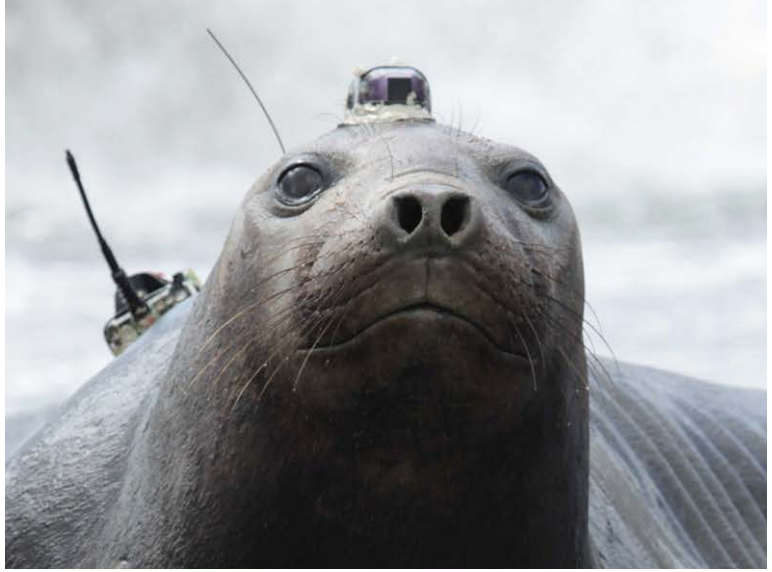


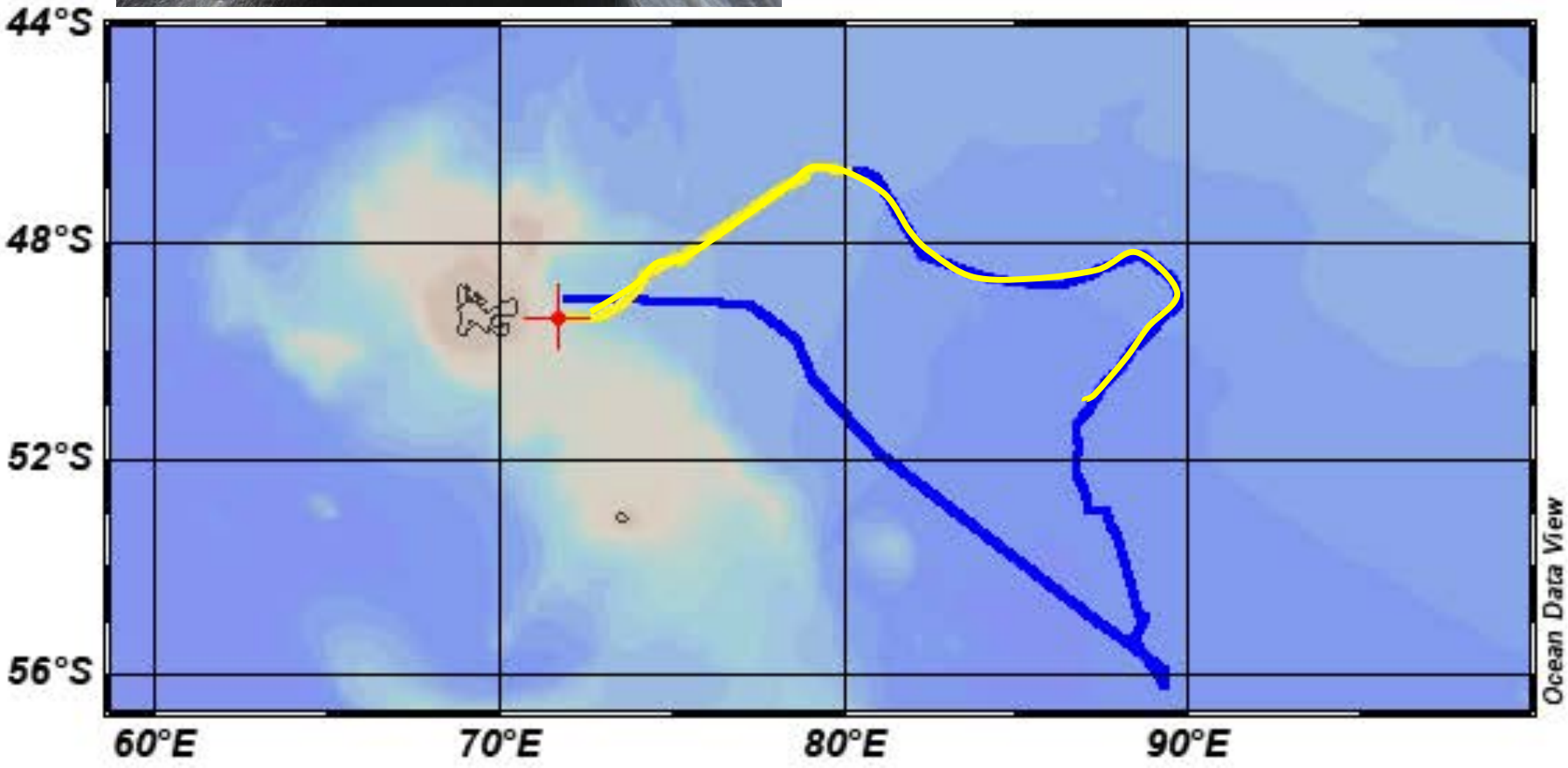


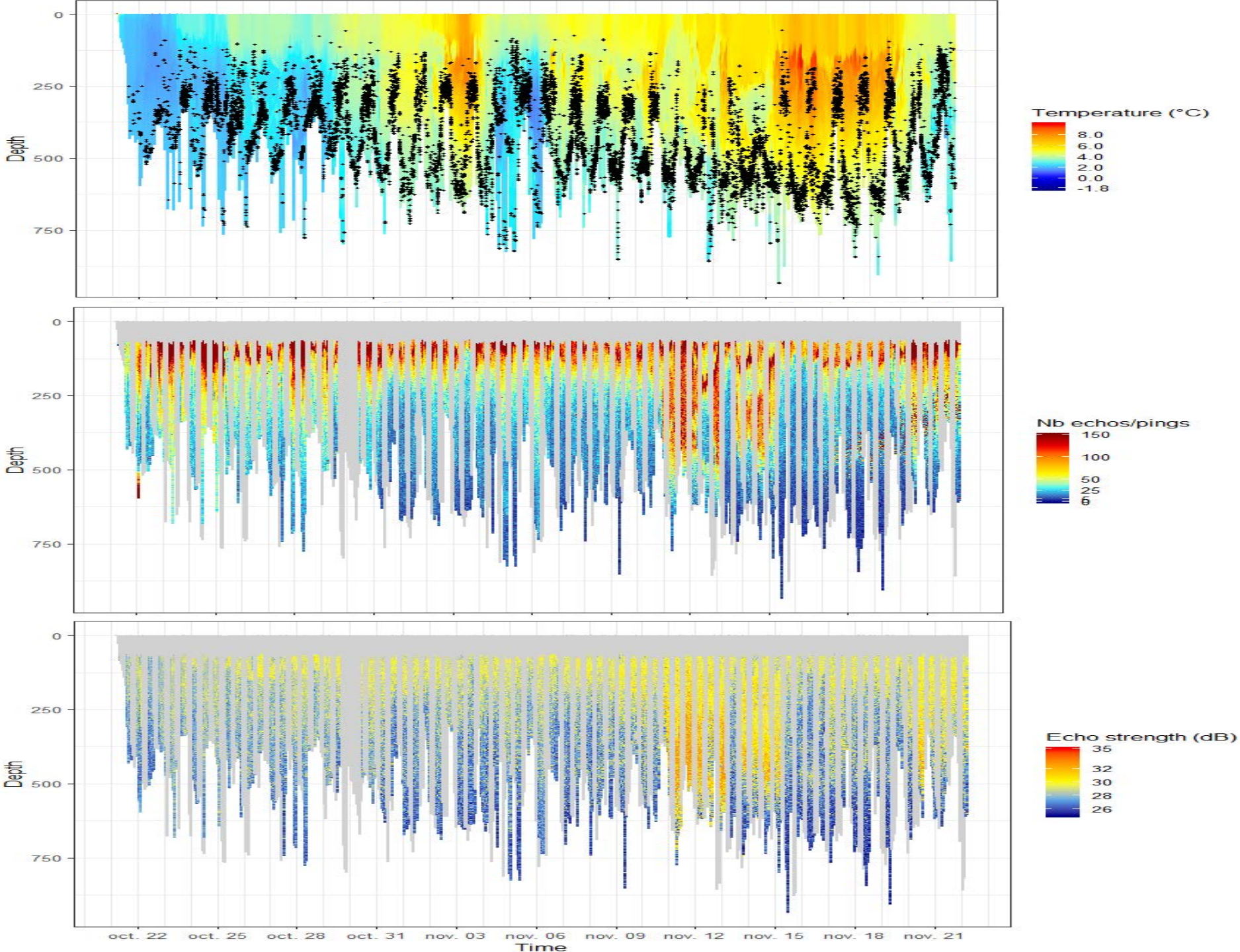


GOULET P, GUINET C, SWIFT R, MADSEN P. JOHNSON M. (2019). A miniature biomimetic sonar and movement tag to study the biotic environment and predator-prey interactions in aquatic animals. Deep-Sea Research Part 1.


Depth (m)
130
135
140
145
0
2
4
142
144
146
148
0
5
10
594
595
596
597
0
2
4
Distance (m)
4
2
0
0
2
4
35
30
25
20
15
ENR (dB)
2
1
0
0
5
10
1
0.5
0
0
2
4
Jerk (m/s3)
2000
1000
0
0
2
4
Time (s)
2000
1000
0
0
5
10
Time (s)
Jerk (m/s3)
2000
1000
0
0
2
4
Time (s)




44°S
48°S
52°S
56°S
60°E
70°E
80°E
90°E
Ocean Data View


Depth
0
250
500
750
Temperature (°C)
8.0
6.0
4.0
2.0
0.0
-1.8
Nb echos/pings
150
100
50
25
6
Echo strength (dB)
35
32
30
28
26
oct. 22
oct. 25
oct. 28
oct. 31
nov. 03
nov. 06
nov. 09
nov. 12
nov. 15
nov. 18
nov. 21
Time

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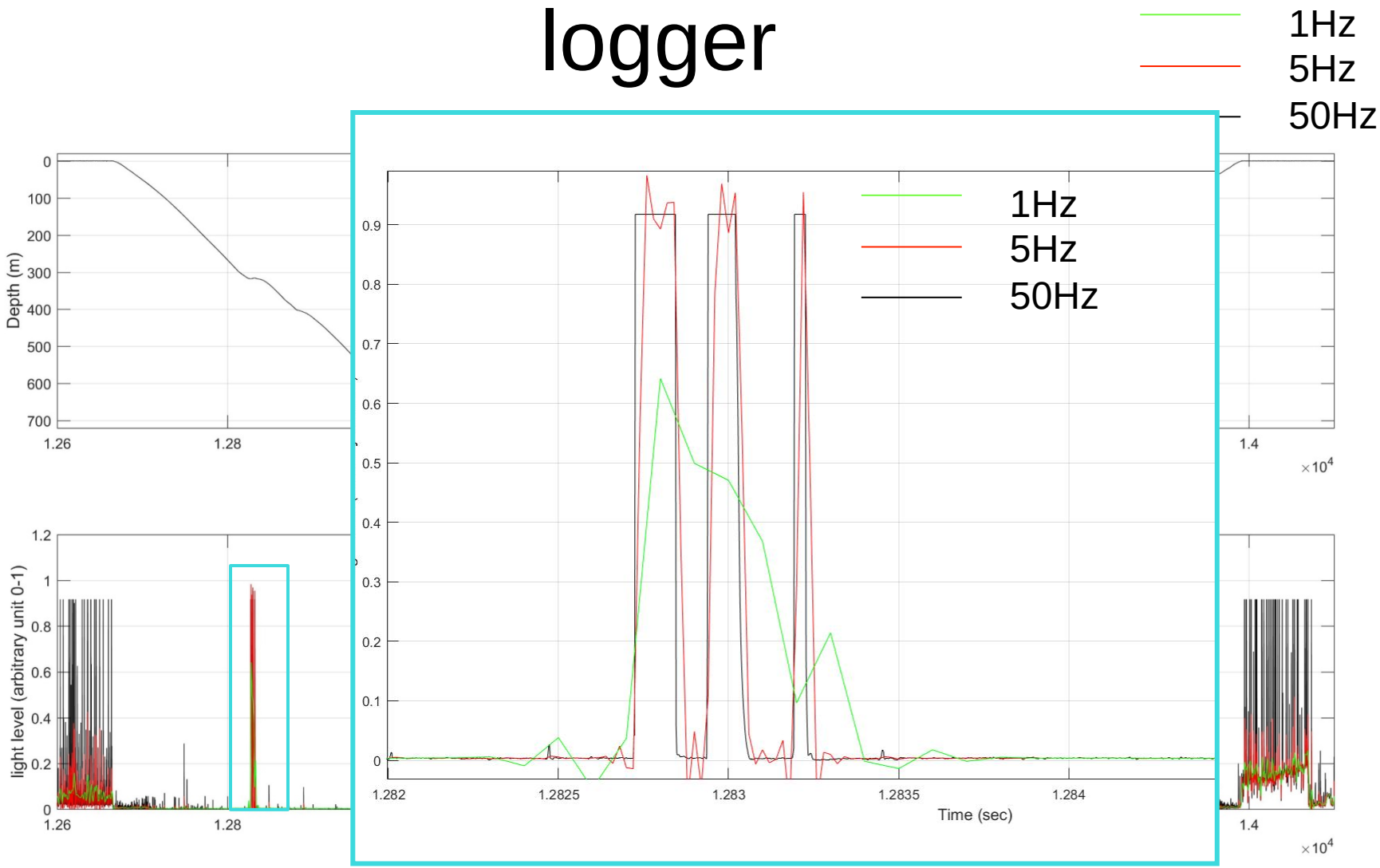
http://biology.st-andrews.ac.uk/seaos/
http://www.annee-polaire.fr/api/MEOP/
http://www.cebc.cnrs.fr/

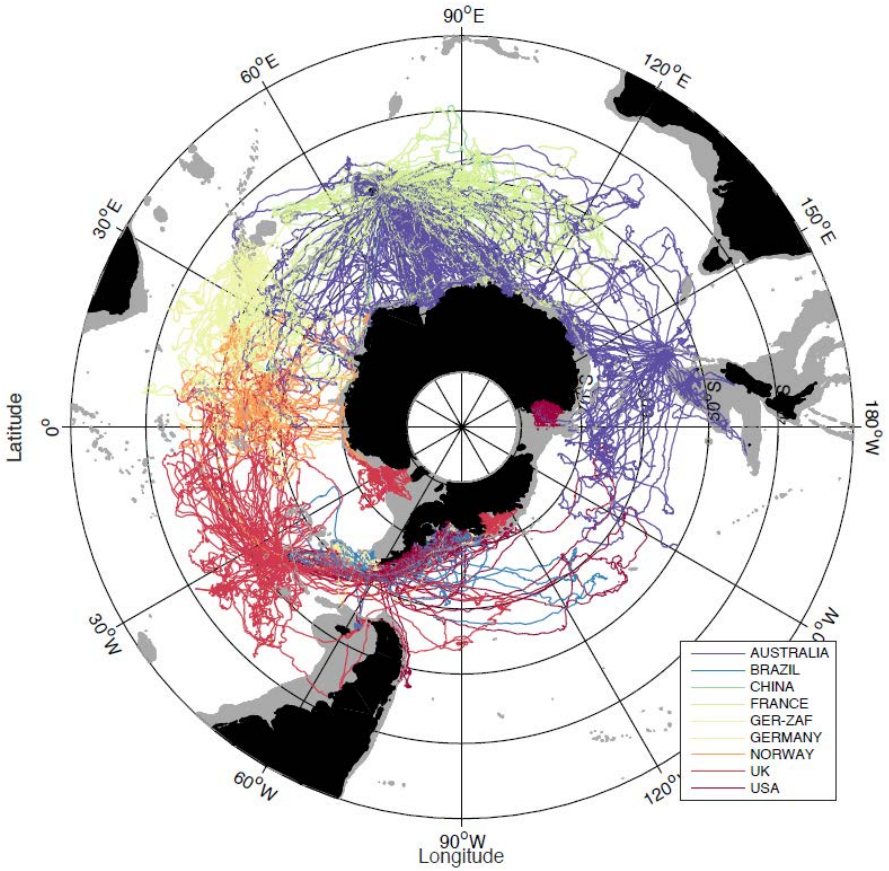
High Frequency sound and light logger



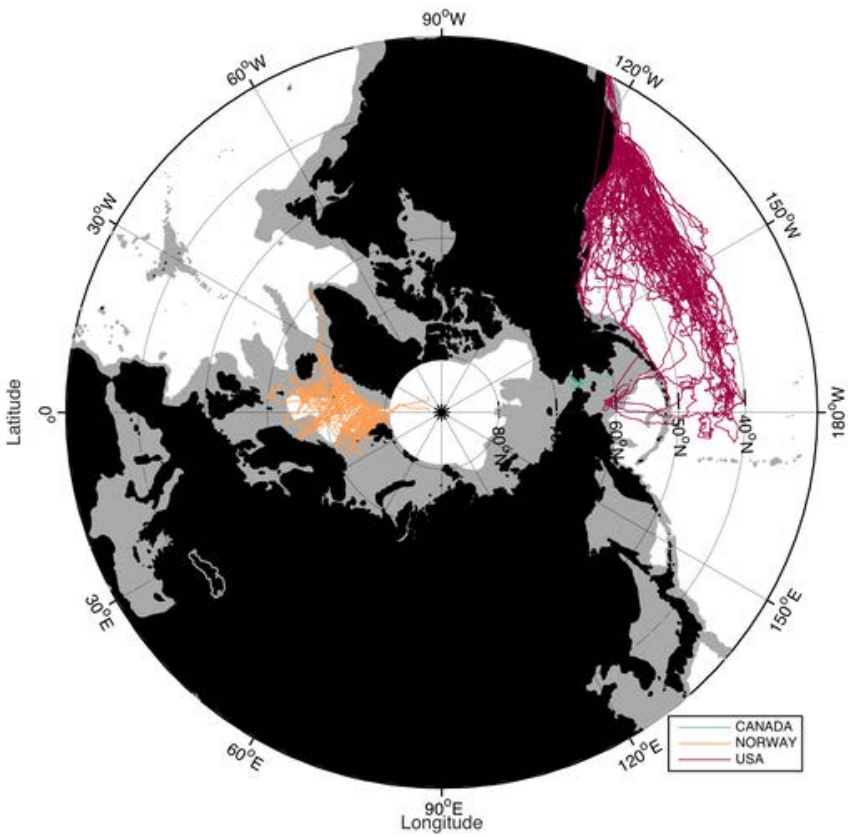
1Hz = « Glow » - Low intensity and continuous
50 Hz = 3 intense blinks!

When diving animals help us to observe the oceans

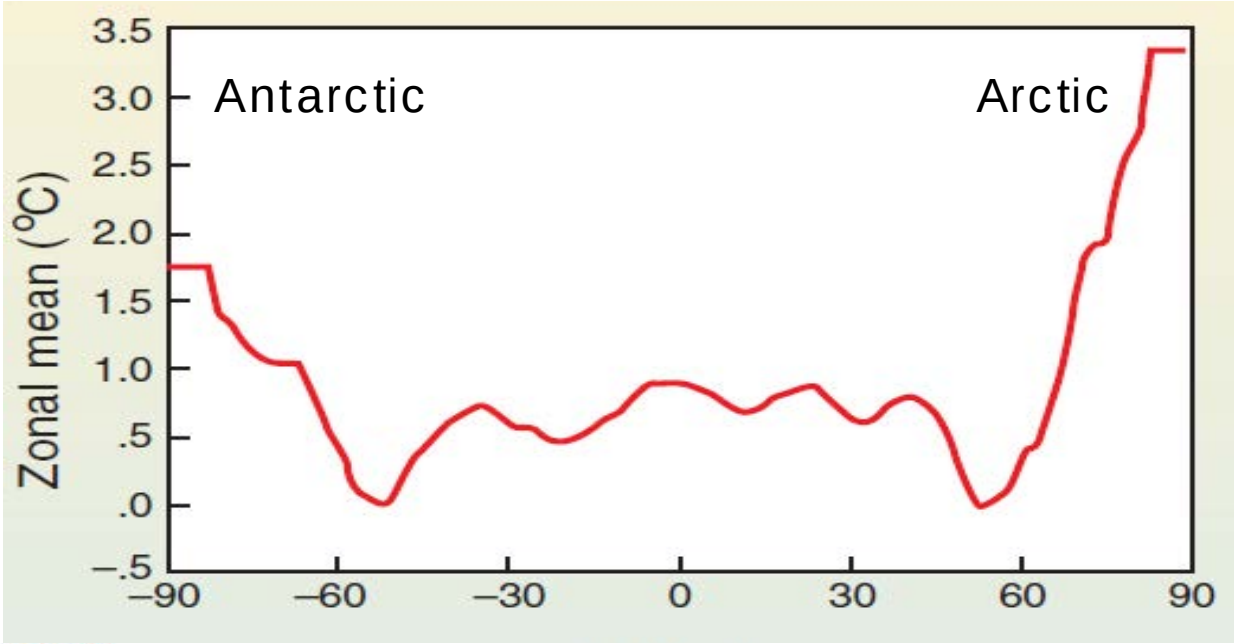
MEOP-CTD SH dataset : 295836 profiles, 81 deployments, 668 tags



MEOP-CTD SO dataset : 27951 profiles, 20 deployments, 89 tags

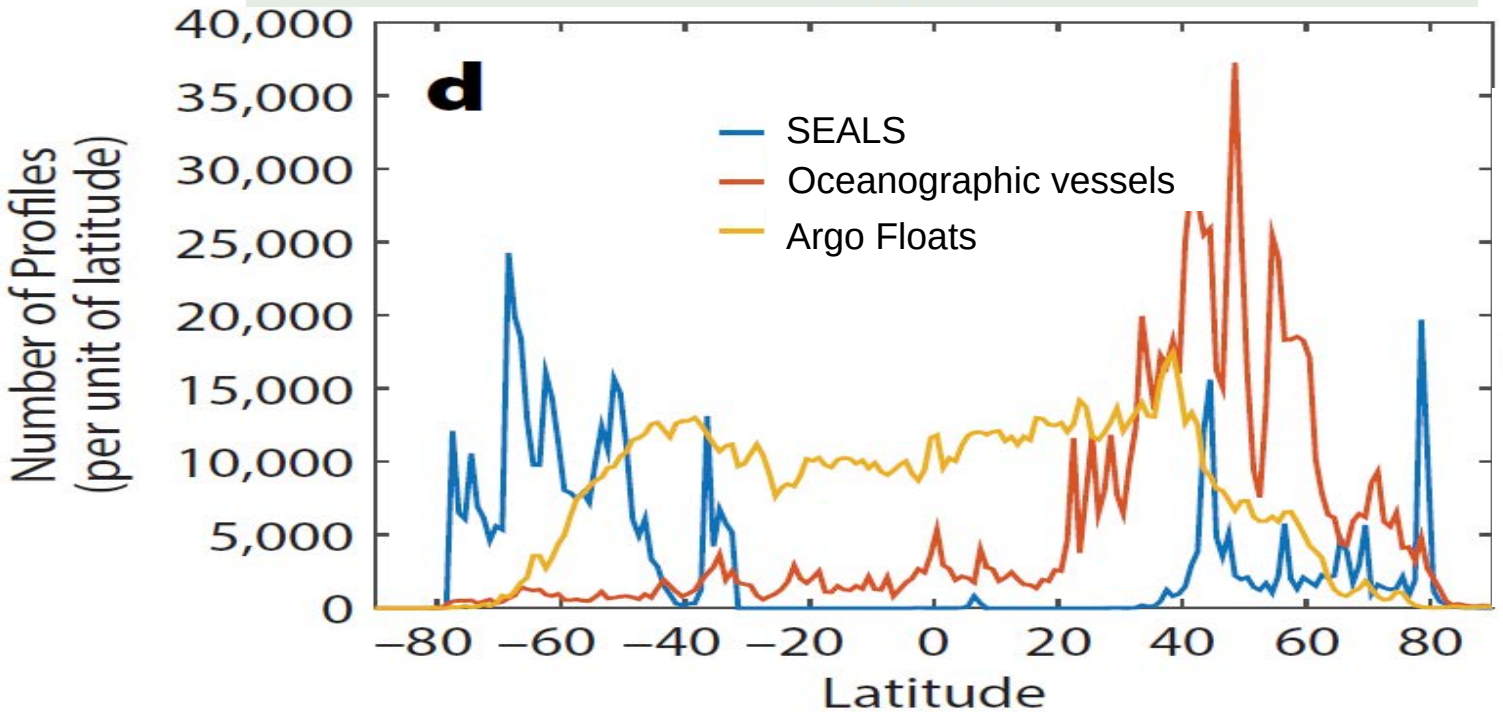


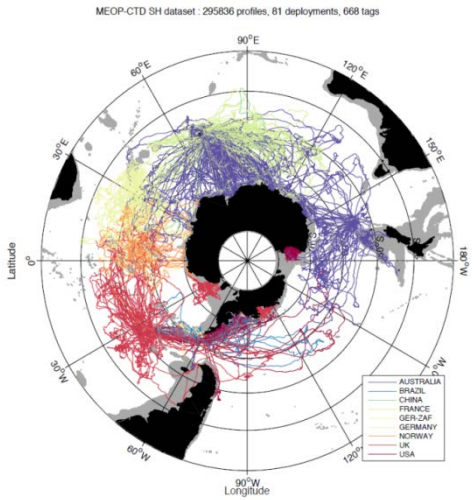
World map showing the distribution of CTD profiles (i.e. vertical profiles of temperature and salinity) currently available in the MEOP-CTD database.
More information on the data distribution can be found on this website.

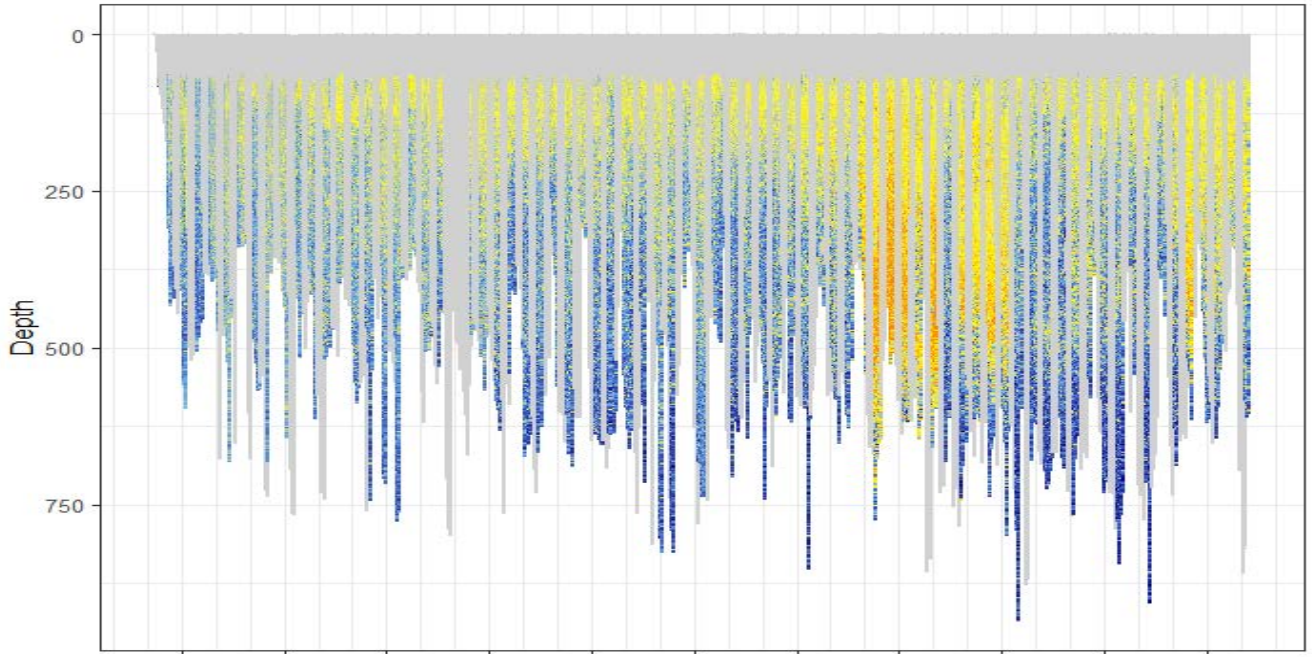


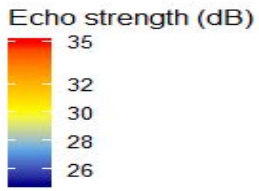
99 % of the profiles within antarctic sea-ice

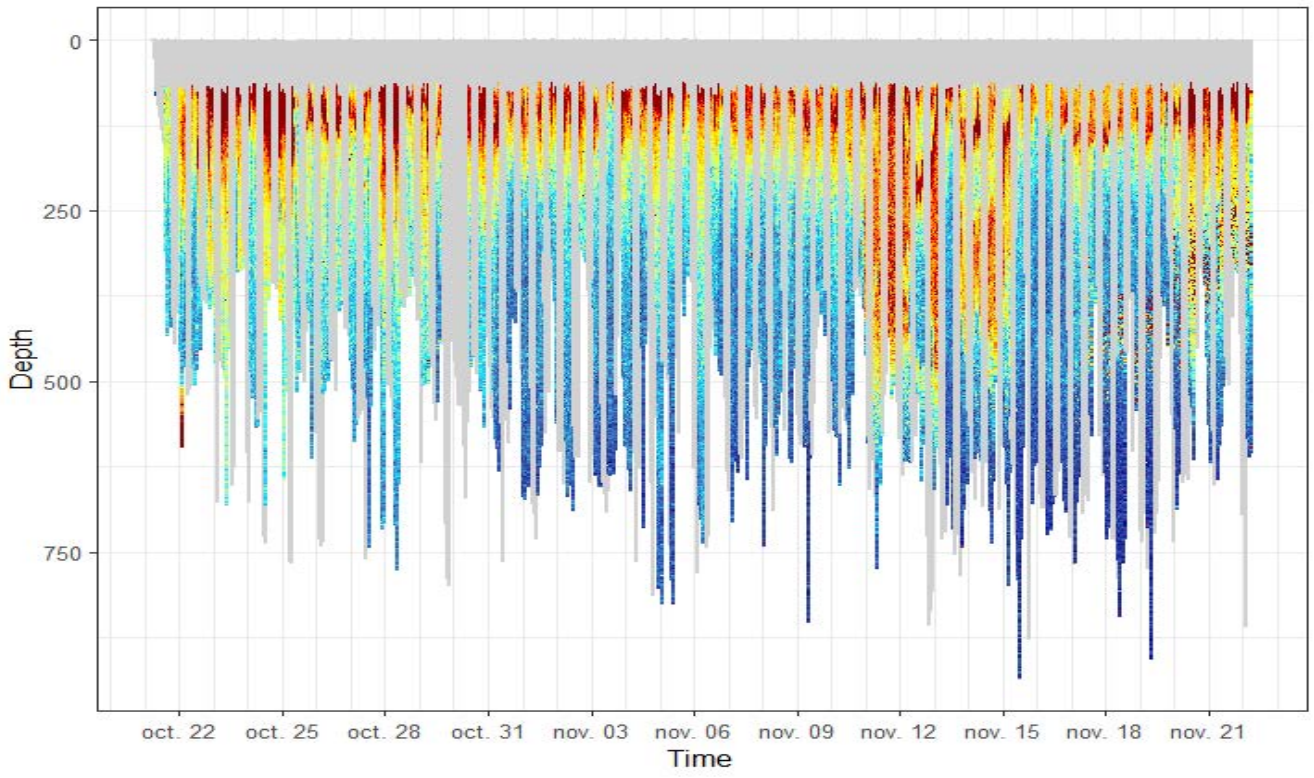
www.meop.net

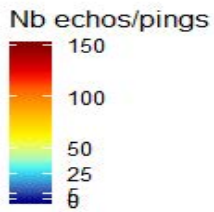


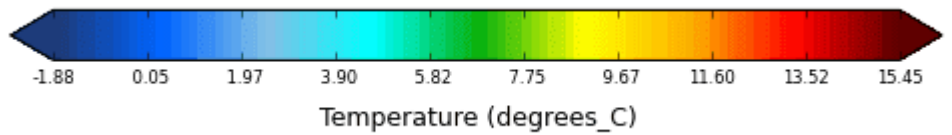


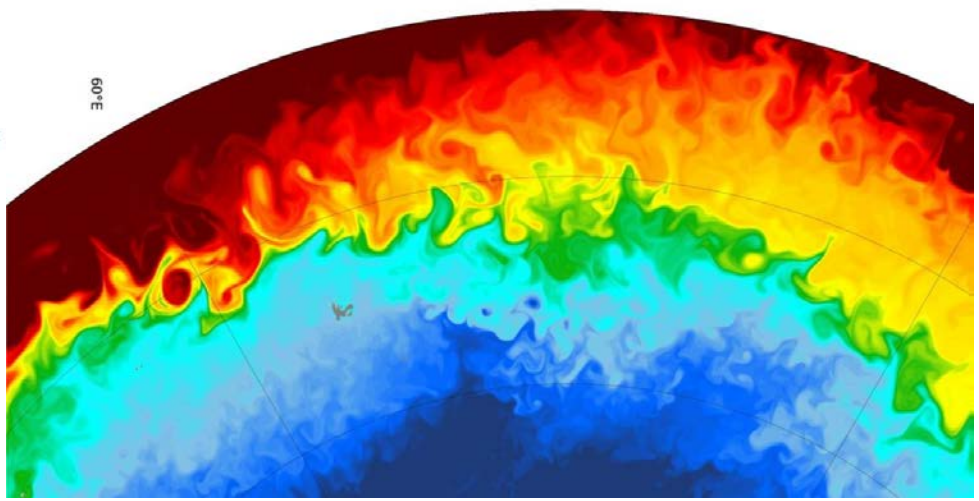

0
250
500
750
Depth


Echo strength (dB)
35
32
30
28
26


0
250
500
750
Depth
oct. 22
oct. 25
oct. 28
oct. 31
nov. 03
nov. 06
nov. 09
nov. 12
nov. 15
nov. 18
nov. 21
Time

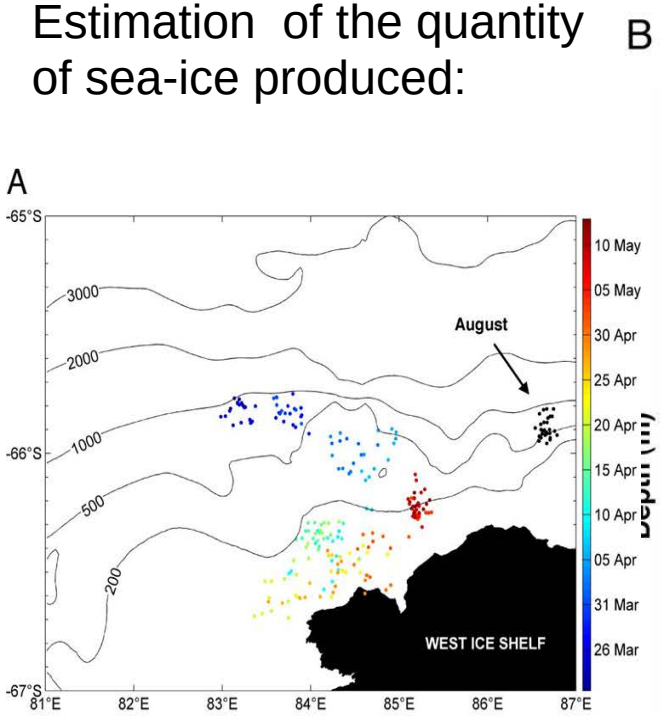

Nb echos/pings
150
100
50
25
0

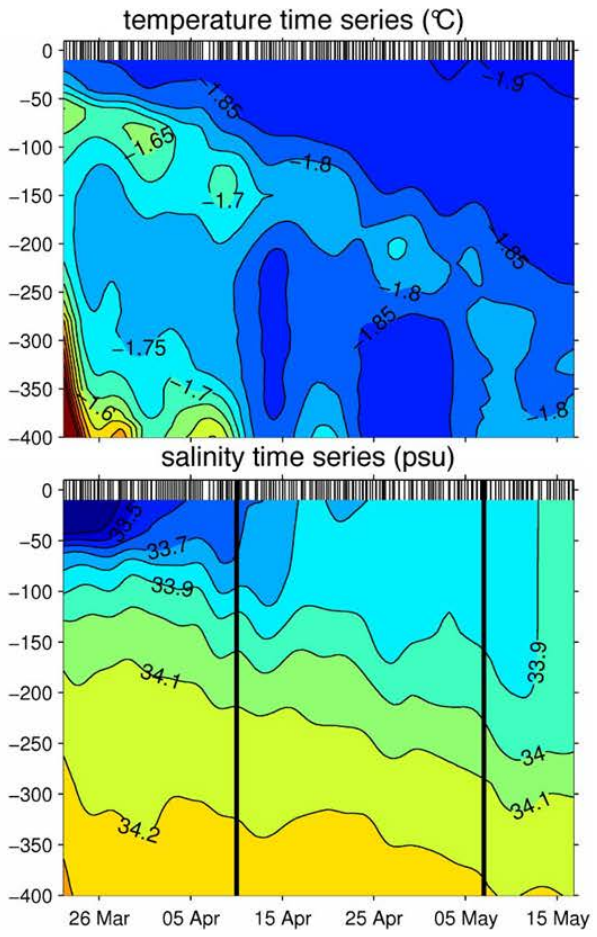

-1.88
0.05
1.97
3.90
5.82
7.75
9.67
11.60
13.52
15.45
Temperature (degrees_C)

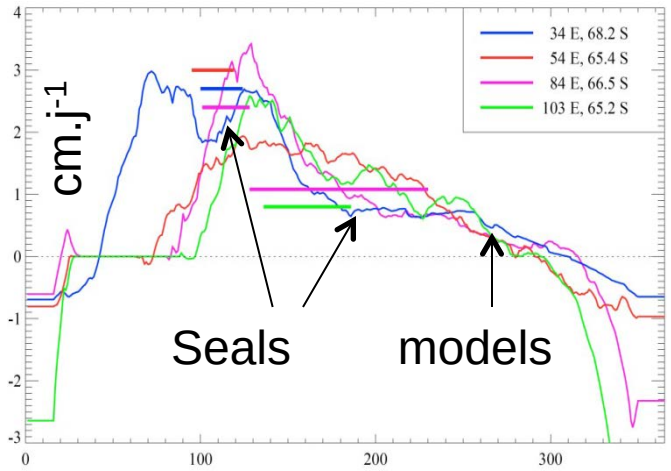

3.09

Sea-Ice extent and thickness (CRYOSAT)

Estimation of the quantity of sea-ice produced:

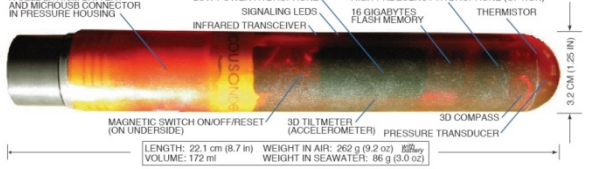


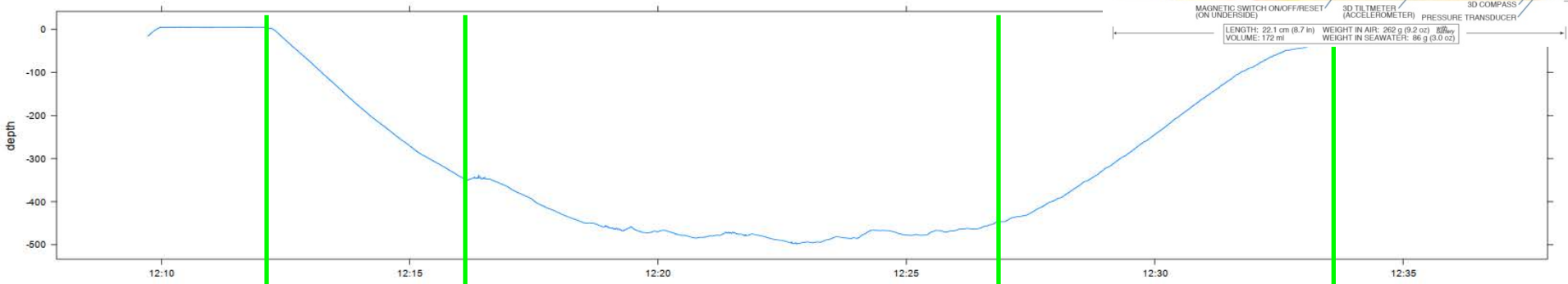


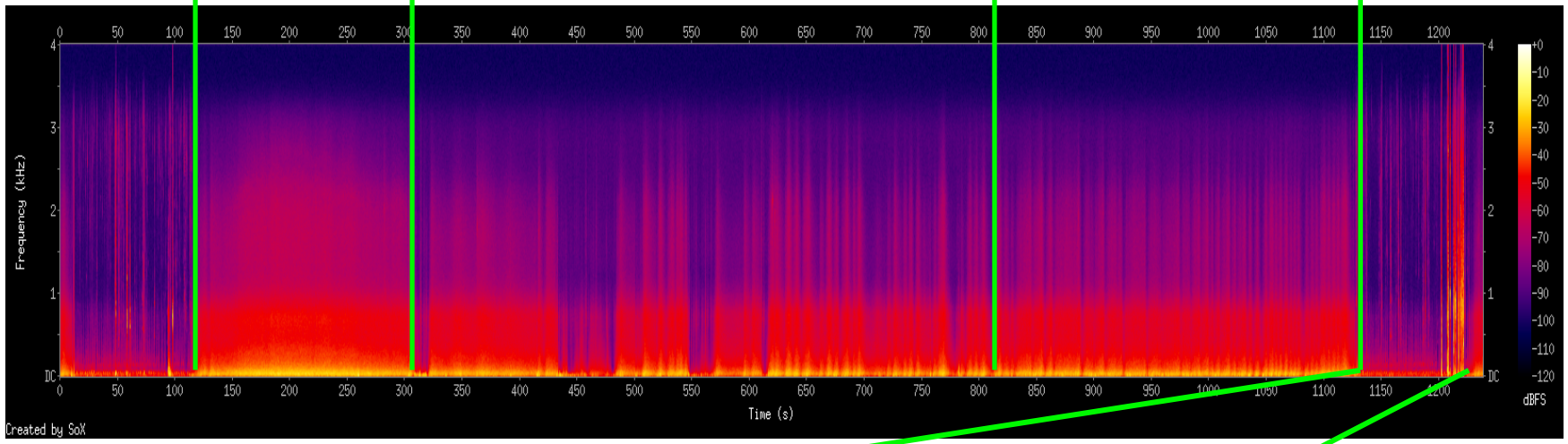


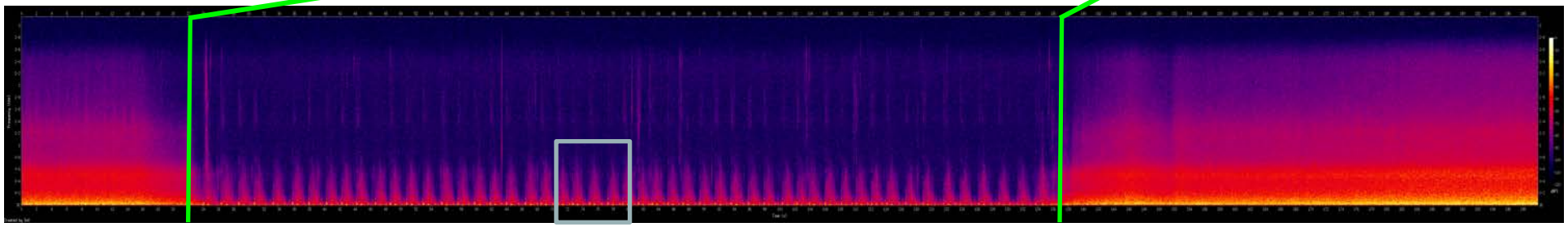
CHARRASSIN J.B., et al. (2008) Southern Ocean frontal structure and sea ice formation rates revealed by elephant seals. Proceedings of the National Academy of Sciences 105:11634-11639

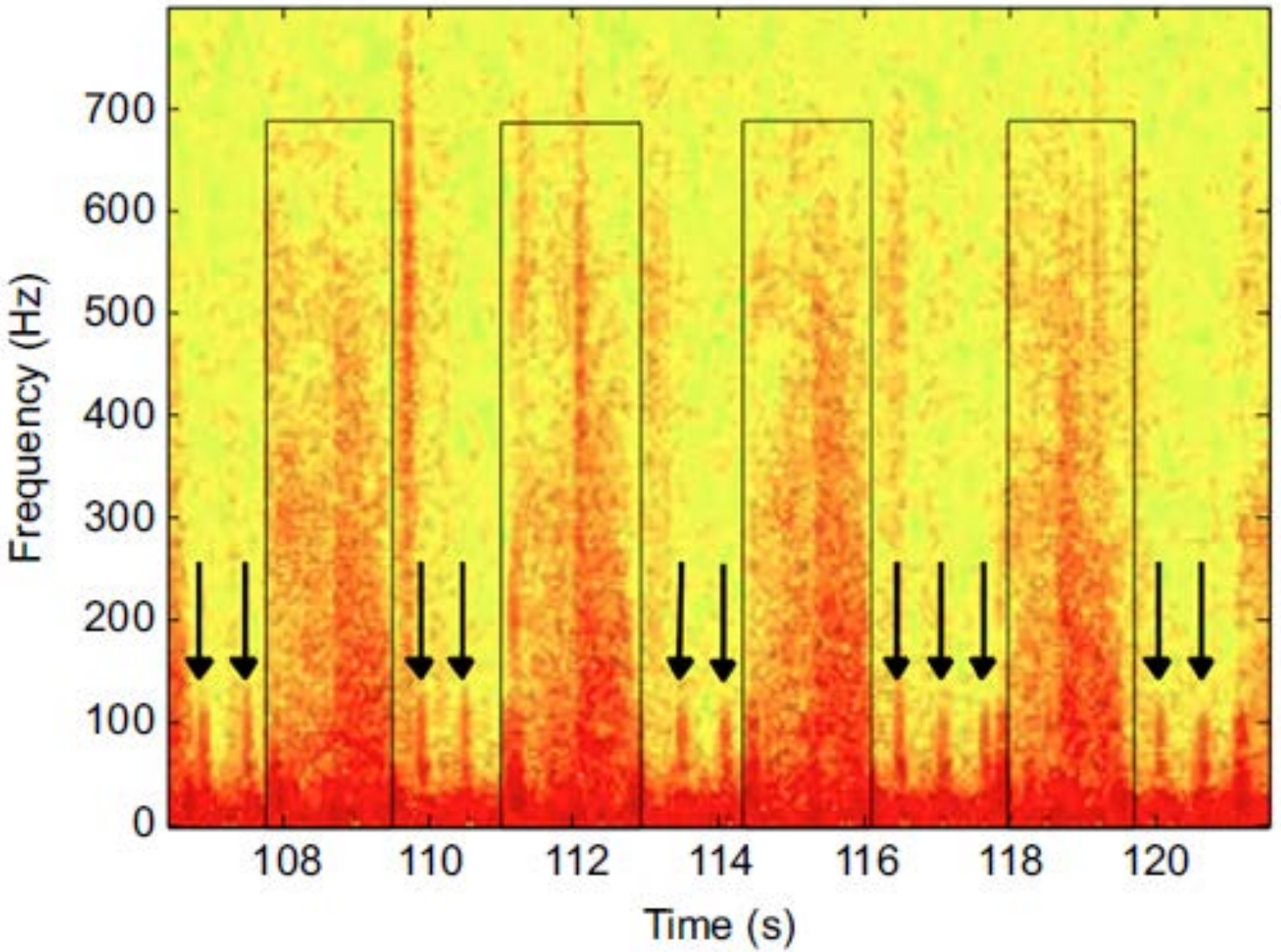
Evaluating the energy expenditure











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.

Reconstruction en Trois dimension de la trajectoire des plongées

(Cédric Pradalier, Georgia Tech Lorraine)