# Passive seismic experiment conducted during the Seamstress2 cruise

## Acquisition report

REM/GM/LAD and CTDI
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Date : 26/04/2021

# Fiche documentaire

| Titre du rapport : Passive seismic experiment conducted during the Seamstress2 cruise | |
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| Résumé/ Abstract : We designed an experiment with an array of five short-period Ocean Bottom Seismometers to study the microseismicity that could be related to fluid activities (surface leakage or deep circulation) at the Lomvi pockmark (Arctic Ocean). | |
| Mots-clés/ Key words : OBS data | |
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<tr><td>Auteur(s) / adresse mail</td><td>Affiliation / Direction / Service, laboratoire</td></tr>
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<tr><td colspan="2">Encadrement(s) :</td></tr>
<tr><td colspan="2">Destinataire :</td></tr>
<tr><td colspan="2">Validé par :</td></tr>
</table>

# Sommaire

# Table des matières

# 1 Context and objectives

## 1.1 Seamstress project

The SEAMSTRESS project aims at quantifying the effect of tectonic forcing on the release of greenhouse gases from the Arctic Ocean floor at depths of 1000 m. The project is led by Andreia Plaza-Faverola (University of Tromsø – CAGE) and supported by the Tromsø Research Foundation (TFS) and the Research Council of Norway (RCN-Frinatek) through two grants.

The project focuses on the influence of tectonic stress on seepage evolution along the 100 km-long hydrate-bearing Vestnesa Ridge in the Fram Strait (Figure 1) where high-resolution seismic data reveal near-vertical faults and fractures controlling seepage distribution. The target of the passive seismic experiment was the Lomvi pockmark (Figure 1) characterized by continuous seepage activity and gas migration (Panieri et al., 2017).

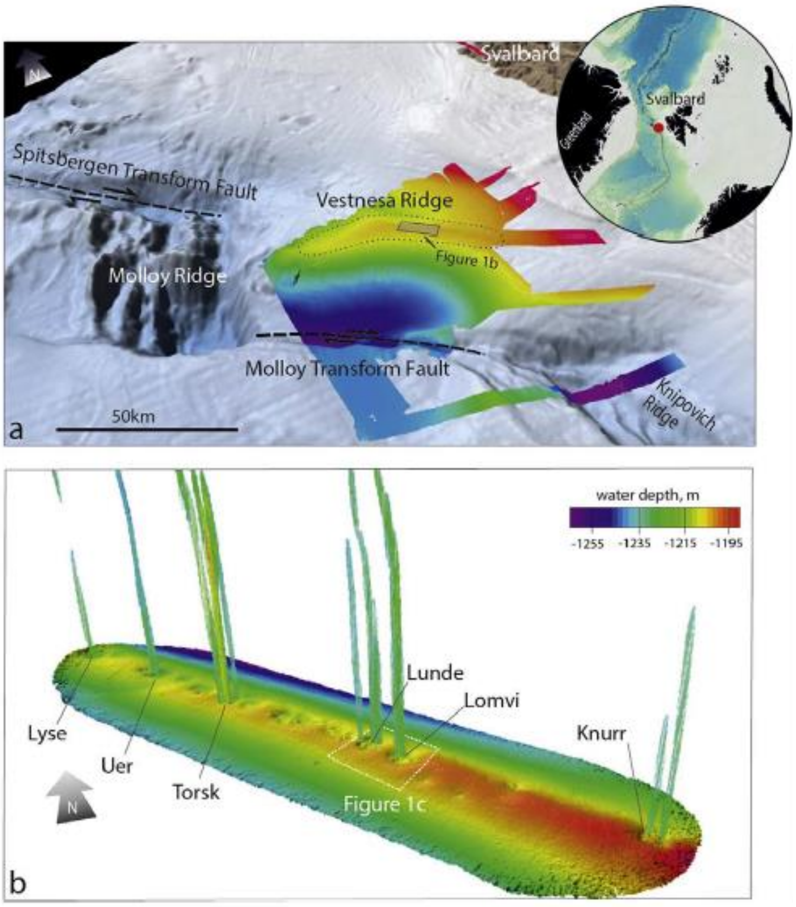


Figure 1: Vestnesa ridge (Artic Ocean): geographical and geological context (a), bathymetry and gas flare location (b) from Panieri et al. (2017).

## 1.2 Technical and scientific objectives

Acoustic techniques, such as single beam (EK60) or multibeam echo sounders have already proved to be efficient in detecting gas emissions in the water column and locating cold seeps on the seafloor worldwide (Dupré et al. 2015; Riboulot et al. 2017). Yet they rarely report on the temporal variability in gas-related processes and are blind to deep-fluid circulation.

The passive seismic approach using ocean bottom seismometers has been proposed for long-term monitoring to study the duration, intensity and periodicity of fluid migration and seepage at the seabed (Tary et al., 2012; Franek et al., 2017; Tsan-Hin-Sun et al. 2019). Signals identified as short-duration events SDE (Franek et al., 2017) or “tremors” (Tsan-Hin-Sun et al. 2019) could be related to bubble emission or fluid circulation but so far, no direct link has been demonstrated. Only a colocation between seepages or gas-charged layers and these signals were observed but no correlation has been established so far with in situ physical quantities related to fluid circulation (pore pressure for instance). Several mechanisms are invoked to explain these signals: i) fluid expulsion from the seafloor, ii) gas migration, resonance of fluid-filled cracks related to fluid migration (Chouet et al., 1988), iii) the cracking itself but there is no solid theory to model the seismic waveforms related to fluid.

The objectives of a short-period passive seismic experiment are two-fold. The first is methodological: how can we define an experiment dedicated to study microseismicity related to fluid circulation?

The second, dependent on the success of the first, is to provide answers to the following scientific questions:

- Can an event such as SDE be recorded on several instruments?
- Can a microseismic event can be correlated to a pore-pressure event?
- Can we identify deep-fault or gas-flare location as sources of microseimic events?
- Can we propose a model based on a solid theory to reproduce recorded signals?

# 2 Acquisition parameters

## 2.1 OBS instruments

For this experiment, we used five short-period OBS (4-component MicrOBSs –Figure 2). Each OBS contains one hydrophone, a vertical geophone and two horizontal geophones. The natural frequency of geophones is 4.5 Hz and the cut-off frequency of the hydrophone is 2 Hz. High-frequency acquisition (1000 Hz) is possible as the experiment is of short duration (three days).

Figure 2: 4-component MicrOBS.

## 2.2 Acquisition location

We developed an experiment with an array of five short-period Ocean Bottom Seismometers located in the Vestnesa sediment ridge in and around the Lomvi pockmark (see map in figure 3 and table 1 for coordinates).

Three instruments formed a line with one inside (OBS3) and two outside the pockmark with increasing distance (OBS1 and OBS2). The two located outside the pockmark had different azimuth with OBS5 close to the piezometer location. The distance between instruments did not exceed 750 m. A broadband autonomous hydrophone (200 kHz) was installed on the piezometer PZ2 (79° 0.285; 6°56.123, 2020/10/21 at 19H45). The autonomy of this instrument was five hours.

| MicrOBSs | Depth | Latitude | Longitude |
|---|---|---|---|
| OBS1 | 1196 | 78°59.86519 | 6°57.39578 |
| OBS2 | 1196 | 79°00.02276 | 6°56.49431 |
| OBS3 | 1137 | 79°00.12687 | 6°55.87014 |
| OBS4 | 1208 | 79°00.37879 | 5°55.73538 |
| OBS5 | 1201 | 79°00.20266 | 6°54.49714 |

Table 1: OBS coordinates

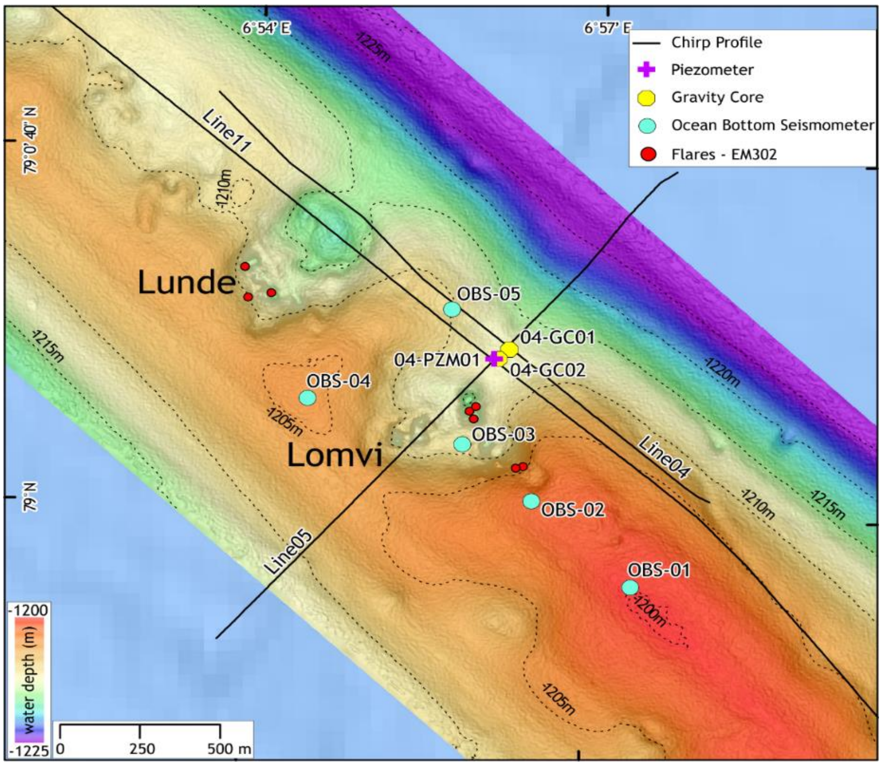


Figure 3: Location of OBS, piezometer, chirp profiles and flares.

## 2.3 Acquisition Parameters

The acquisition parameters used for this experiment are described in table 2. A low gain setting was used to prevent saturation. An FIR filter was applied to maintain the low frequency content of recorded signals. Drift time was recorded when SAC files were generated with the values indicated in Table 3 with the exception of OBS3 for which drift computation was not applied.

The instruments were deployed October 21, 2020 and recovered October 25, 2020.

We were able to exploit a time series of a duration of ~3 days with all instruments recording at the seafloor and without the presence of the research vessel starting from October 21, 21h30.

| **MicrOBS Setup Parameters** | |
|---|---|
| Sampling Frequency | 1000 Hz |
| Hydro/geo Gain | 20 dB / 26 dB (1x/2x) |
| Filter option | FIR2 |
| **Hyrdophone Setup Parameters** | |
| Sampling Frequency | 512 kHz |
| Time shift (ms): | +50 |

Table 2: OBS and autonomous hydrophone setup parameters

| **MicrOBSs** | **Synchro** | **Drift time** | **Drift correction (ms)** |
|---|---|---|---|
| OBS1 | 2020/10/20 11:44 | 2020/10/25 8:47:59 | -9 |
| OBS2 | 2020/10/20 12:05 | 2020/10/25 12:07:59 | -78 |
| OBS3 | 2020/10/20 12:20 | / | u |
| OBS4 | 2020/10/20 12:30 | 2020/10/25 19:11:59 | -13 |
| OBS5 | 2020/10/20 11:40 | 2020/10/25 19:15:00 | 5 |

Table 3: Time drift

# 3 Data-quality control

## 3.1 DC Component

As the FIR2 was set, it was possible to record the DC component of each sensor for all instruments (Figure 4). Even if OBS1 shows the same DC component for all sensors, the four other instruments show different DC values. Sensors are associated in pairs (hydrophone/X geophone and Z geophone /X geophone) sharing the same DC value. The DC values of these two pairs are quite different. The offset related to the DC component must be considered to avoid saturation issues.

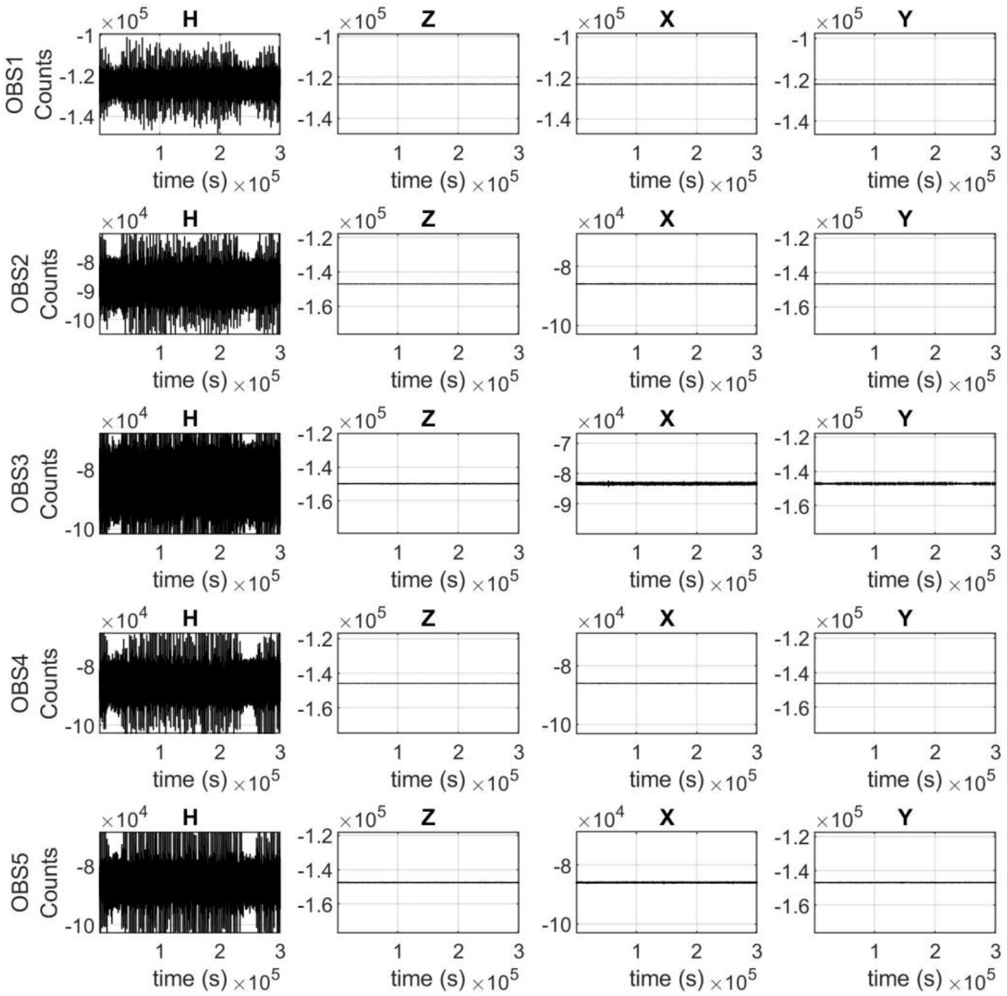


Figure 4: DC component for all sensors and all instruments.

## 3.2 OBS3 amplitude anomaly

Figure 5 displays the mean amplitude value of the Fourier Transform of each hydrophone (the DC component is filtered out). As the deployment of the instrument is easily deduced from this value, it is also obvious that once at the seafloor OBS3 shows a higher value. To control whether the higher amplitude is related to a problem in gain calibration or a different coupling of the OBS structure with the seafloor, the mean amplitude was extracted from recording on the deck before deployment (Figure 6). This higher level of the OBS3 is present. The instrument must be calibrated to check and correct this possible anomaly.

Control of geophone sensors is more challenging as the response depends on the coupling, possible tilt and orientation (Figure 7). Nevertheless, a higher value is observed for the vertical geophone of OBS3 on measurements made on the deck (Figure 8).

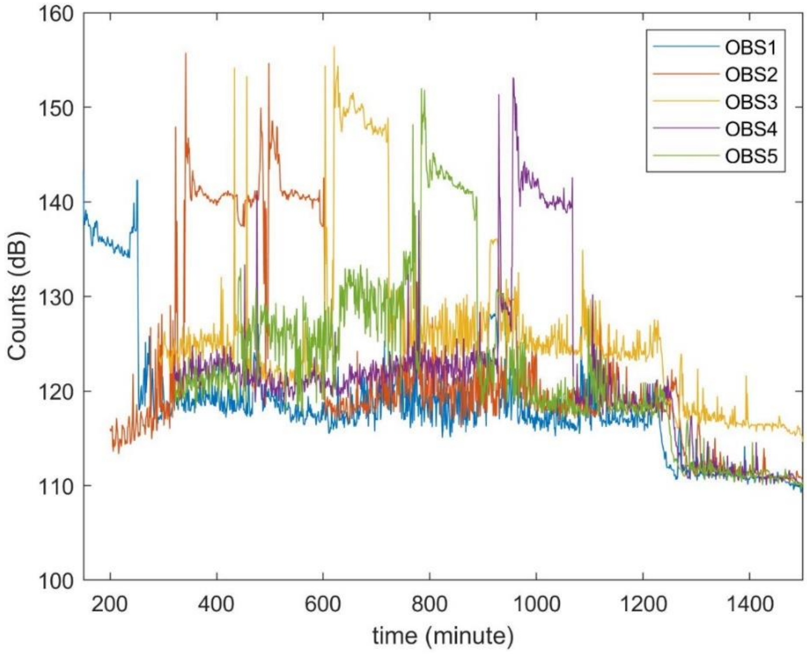


Figure 5: Mean amplitude value of the Fourier Transform of each hydrophone during OBS deployment and when all instruments are on the seafloor (time>1100 minutes)

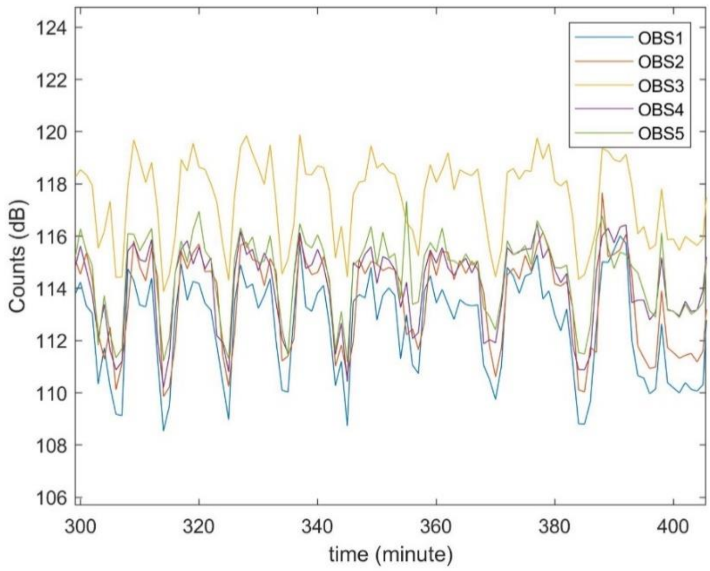


Figure 6: Mean amplitude value of the Fourier Transform of each hydrophone with all instruments on the deck (different time reference)

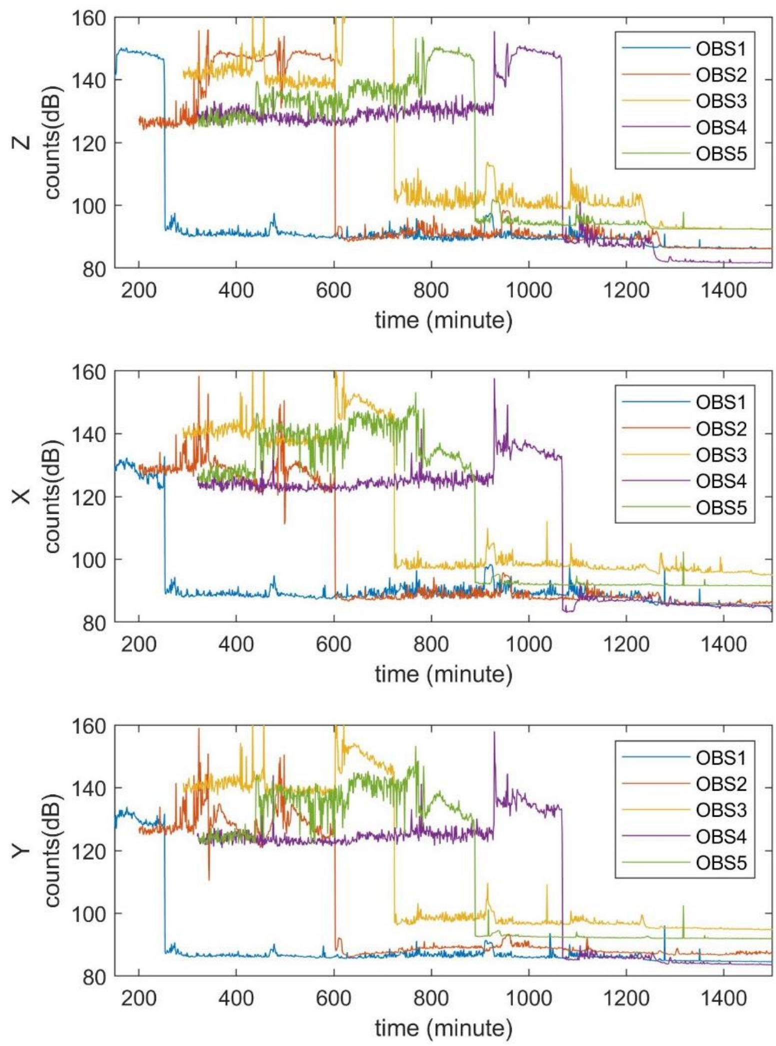


Figure 7: Mean amplitude value of the Fourier Transform of each geophone during OBS deployment and when all instruments are on the seafloor (time>1100 minutes)

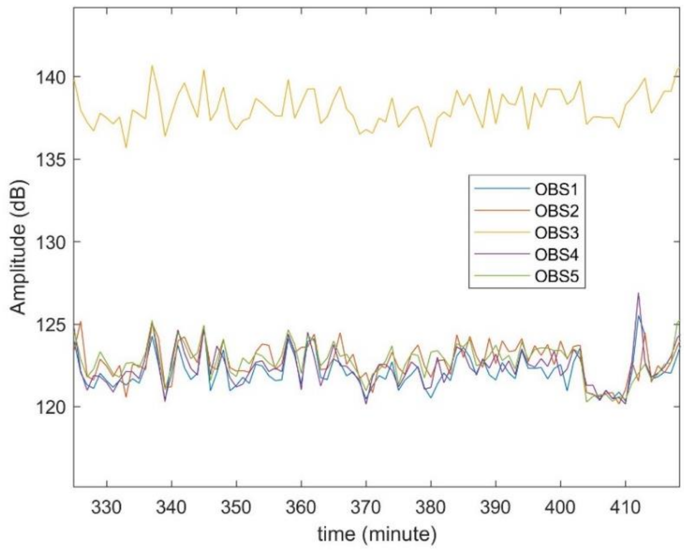


Figure 8: Mean amplitude value of the Fourier Transform of each geophone with all instruments on the deck (different time reference)

## 3.3 Frequency analysis

A spectrum analysis of hydrophone data is presented in figures 9 and 10. A high DC component and a higher level of OBS 3 are evident. Several frequency peaks are observed. These peaks are related to the ship noise. Two broader peaks of amplitude are visible: one at very low frequency and the second around 20 Hz.

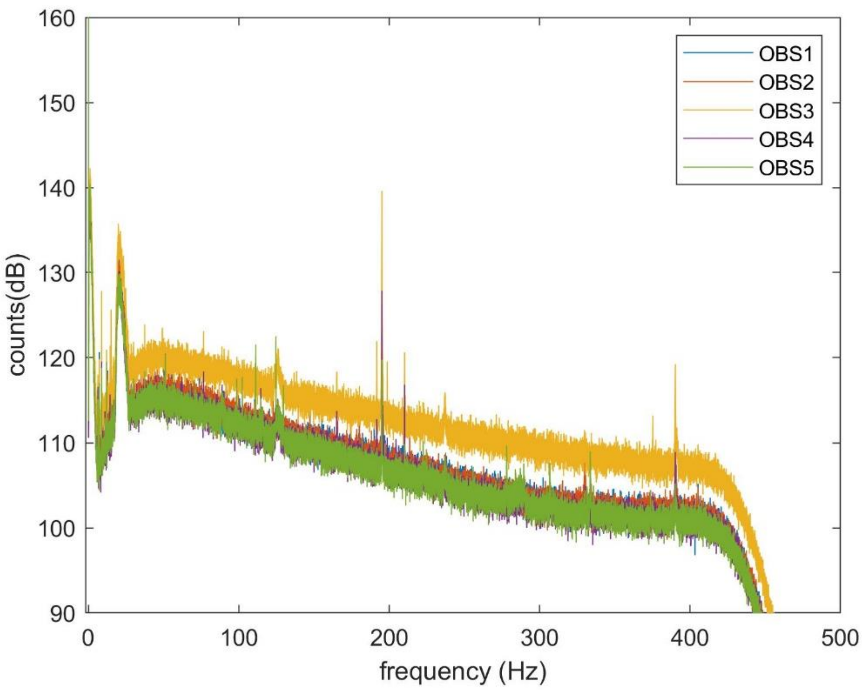


Figure 9: Amplitude spectrum of hydrophone data

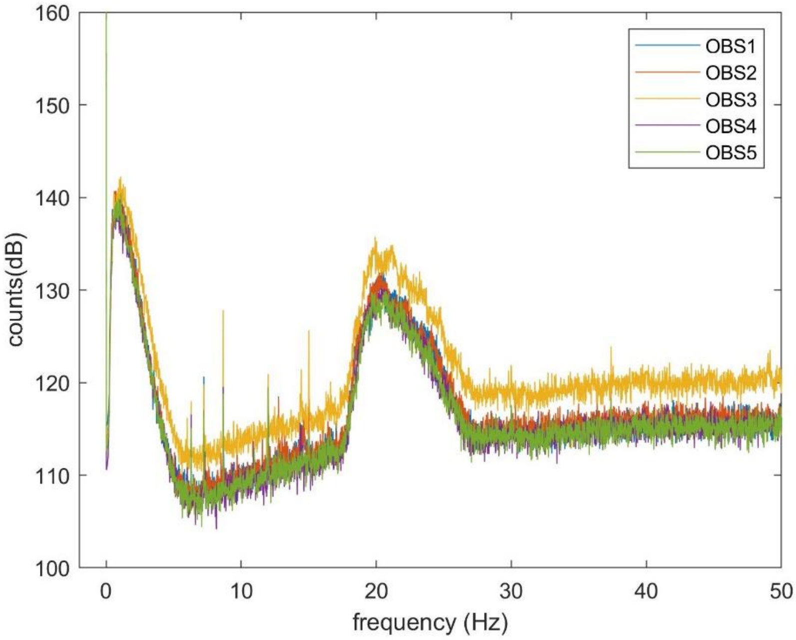


Figure 10: Amplitude spectrum of hydrophone data- close-up below 50Hz

A spectrum analysis of geophone data is presented in figure 12. An SDE event is responsible for the frequency component around ~8 Hz for OBS3. Conversely, the Z spectrum is flat for frequencies higher than the natural frequency of the geophone. The 20 Hz peak is also detected on horizontal geophones.

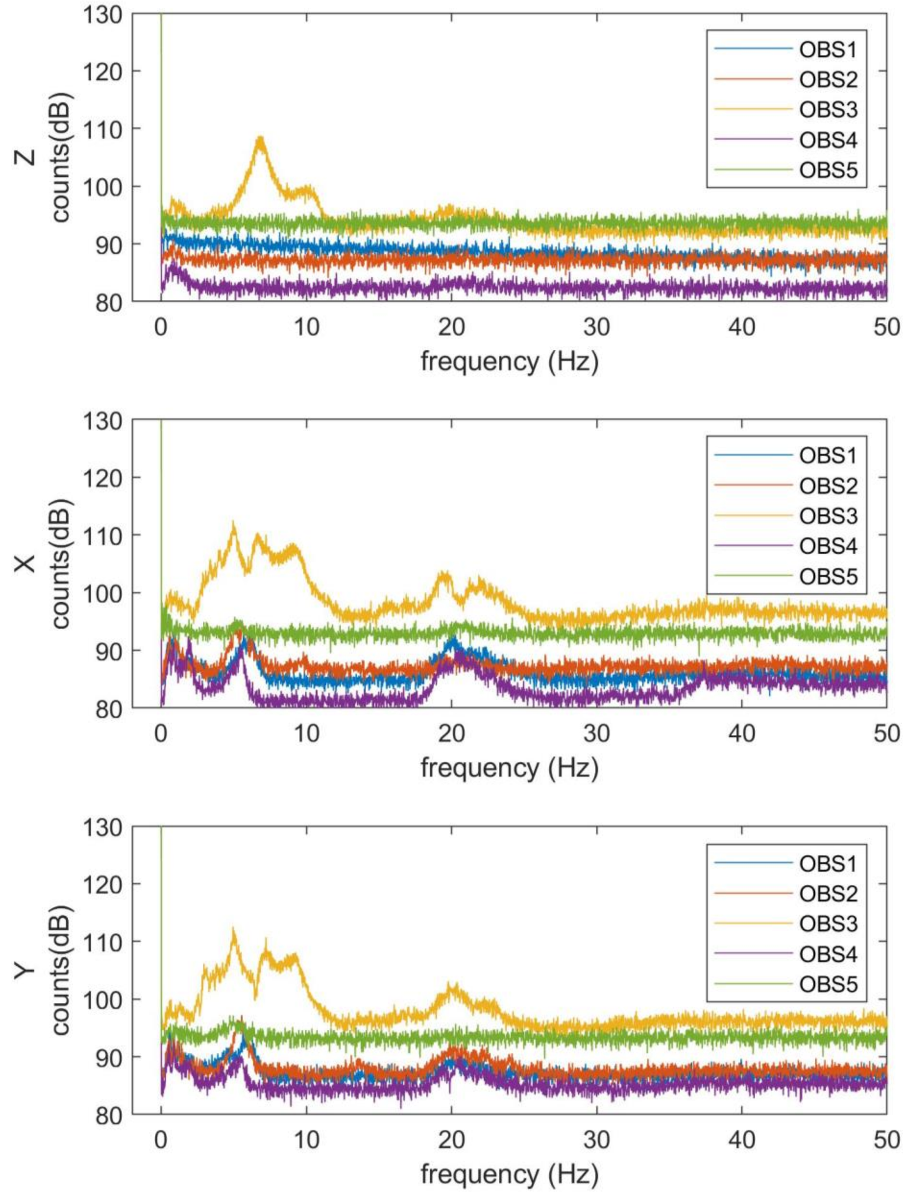


Figure 11: Amplitude spectrum of geophone data

# 4 Recorded signals

## 4.1 Earthquake signals

We identified two earthquake signals:

- October 22, at 20H09 (figure 12),
- October 24, at 6H22.

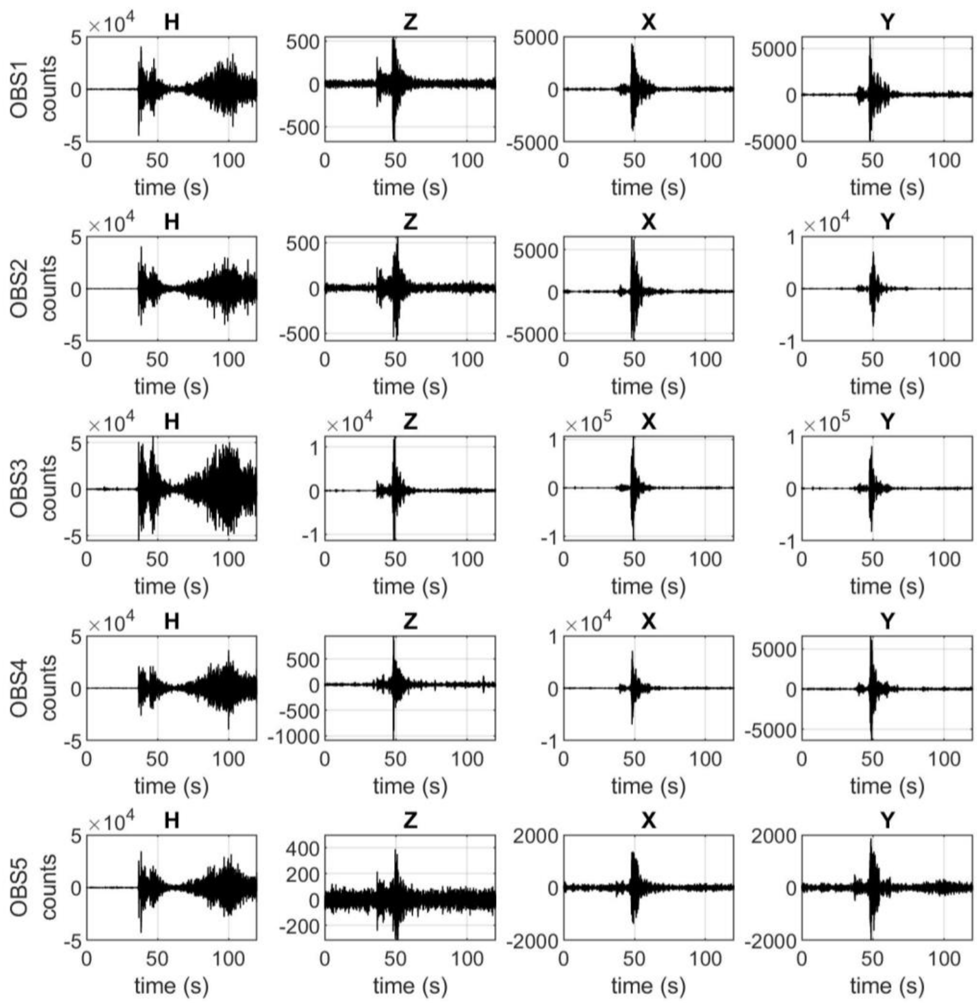


Figure 12: Earthquake signals recorded on all sensors.

The T phase is easily identified on hydrophone data (Figure 13)

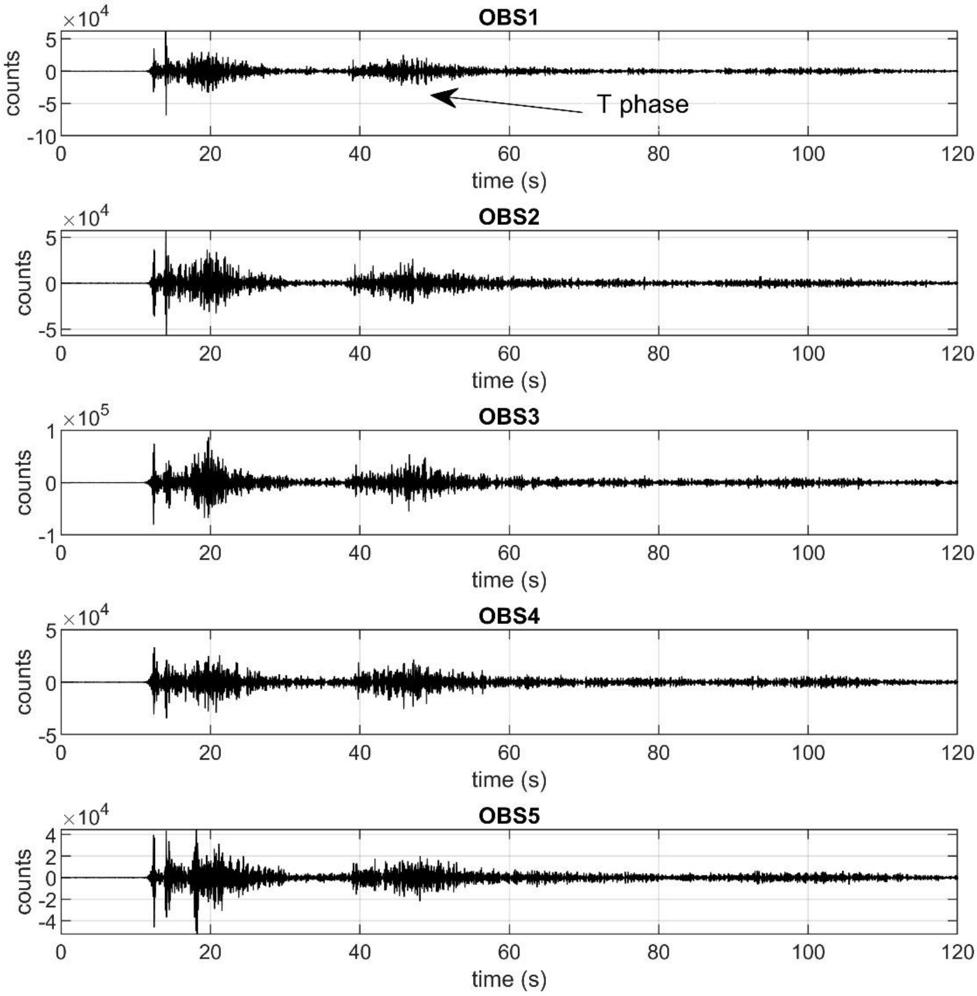


Figure 13: T phase recorded on hydrophone data.

## 4.2 Fin whale signals

The 20 Hz component is related to fin whale signals. This signal is a frequency modulation between 18-26 Hz emitted every 10-12s (Figure 14-15).

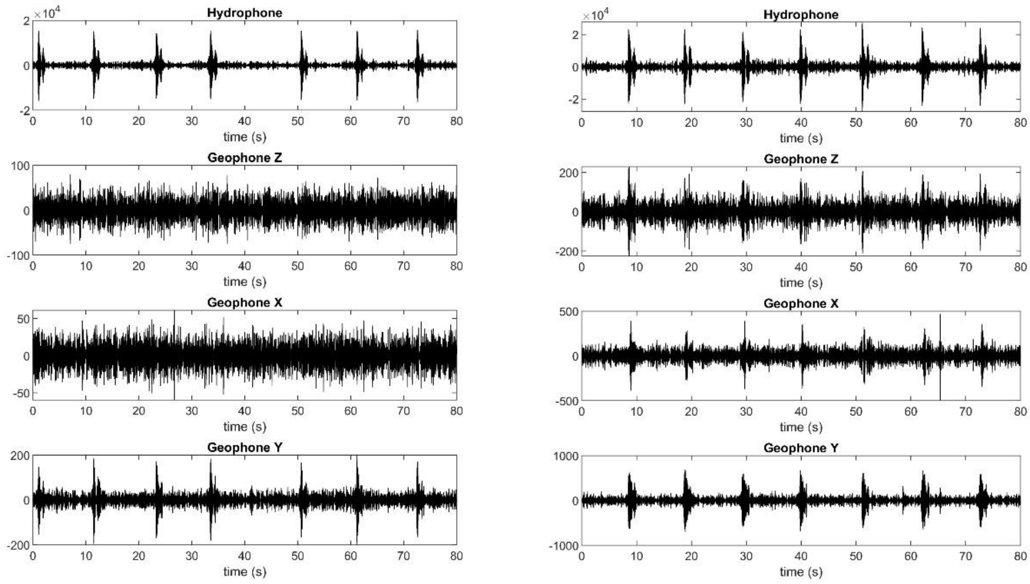


Figure 14: Fin whale signals recorded by OBSs 1 (left) and 3 (right).

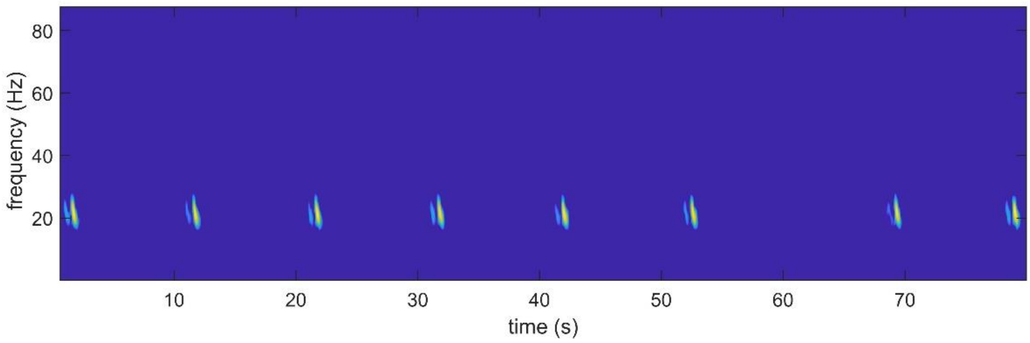


Figure 15: Time-frequency analysis of fin whale signals

## 4.3 Short and long duration signals

Short (<1 s) and long (~10 s) signals were recorded. Short-duration signals were identified on a single instrument with a few exceptions. Long-duration signals were recorded on all hydrophones and some geophone sensors. Examples of these two signals are displayed in figures 16 and 17.

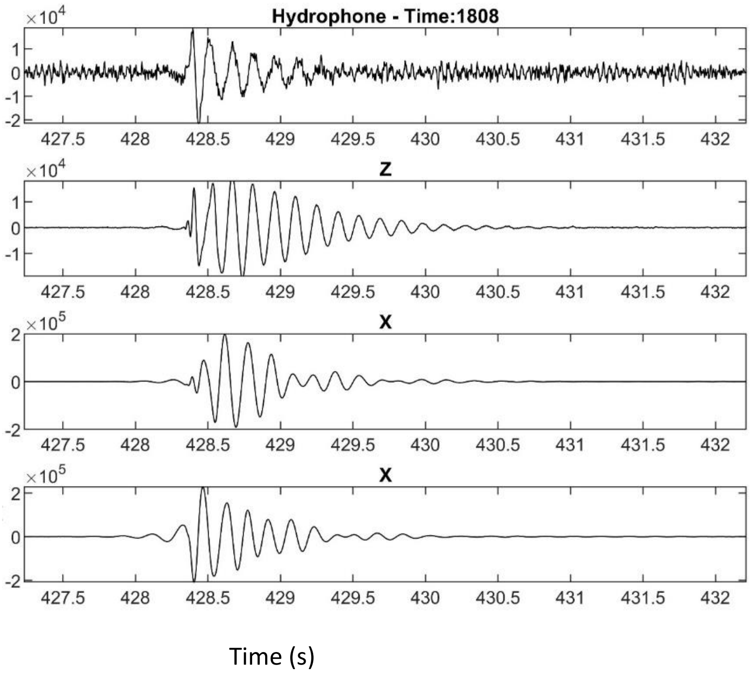


Figure 16: Example of impulsive signal (SDE) recorded on a single instrument.

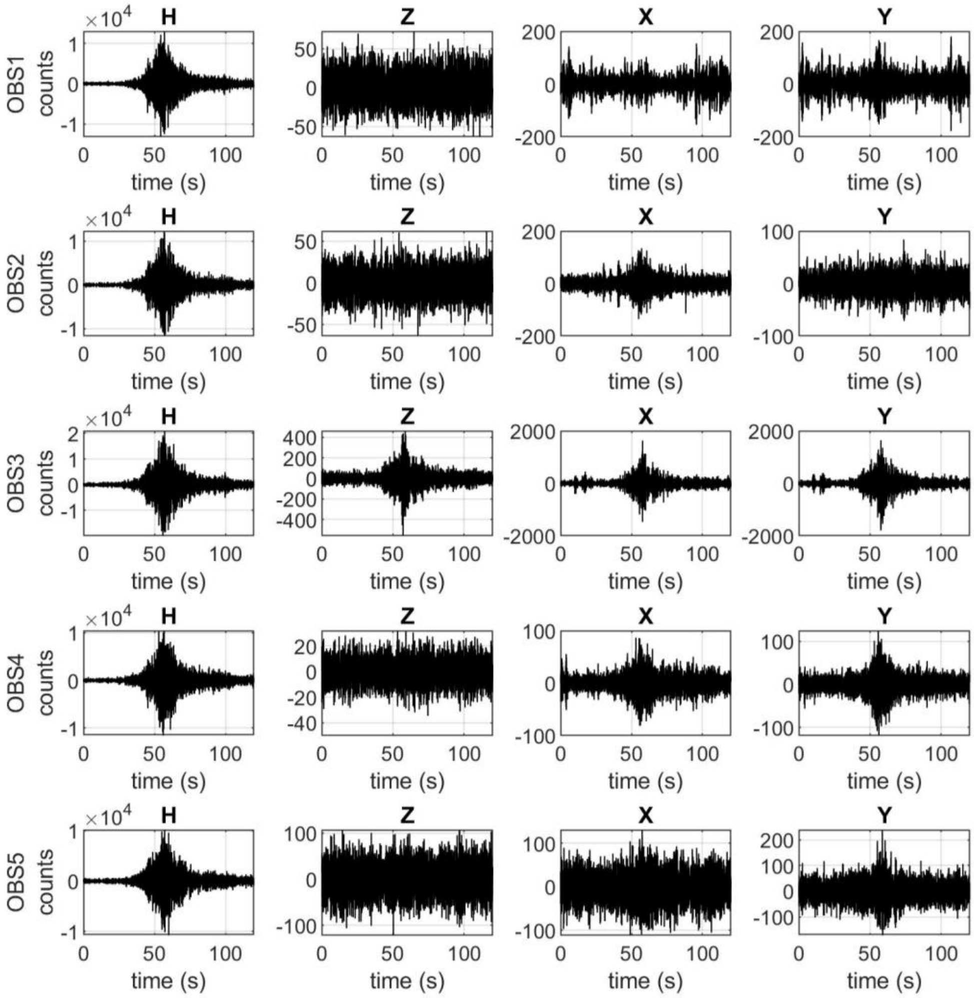


Figure 16: Example of long duration signal (LDE) recorded on all instruments

# 5 References

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# Annex : recording sheets

OBS1

## FICHE PROGRAMMATION MicrOBS

**Déploiement**

| | | | |
|---|---|---|---|
| Projet | STR2 | Programmé par | Stéphan |
| n°station | OBS1 | Vérifié par | Nabil |

**identification MicrOBS**

| | | | | | |
|---|---|---|---|---|---|
| N° MicrOBS | 178-058 | Code largage | OFE | canal VHF | 72 (156,625MHz) |
| | | Code arrêt larg | F01 | | |

**Programmation de la plongée**

| | | | | | |
|---|---|---|---|---|---|
| Experiment | STR2 | Sync | 20/10/2020 11/43 | Tension (vbat) | 16,32 |
| Deployment | OBS1 | Start recording | Immediately | Pression (pres) | 567 |
| Sample | 1 | End recording | Endless | | |
| Channels | 4 | Time release | 25/10/20 22:30 | Filtre | FIR2 |
| Gain | 1/2 | Espace libre (Go) | 8 | Led acq marche | 4 |

**Vérifications fin programmation**

| | | | | | |
|---|---|---|---|---|---|
| Courant on | 287 | Serrage connect | ok | Flash | ok |
| Courant off | 0 | Serrage bouchons | ok | VHF | ok |
| | | Bouchon prise vide | ok | led acq marche | 4 |

**Vérification mise à l'eau**

| | | | | | |
|---|---|---|---|---|---|
| Drapeau | ok | Serrage bouchons | ok | Mise à l'eau (h) | |
| Anneau | ok | | | | |
| | | led acq marche | 4 | Profondeur (m) | 1196 |
| Serrage lest | ok | | | Latitude (°) | 78°59.852 N |
| stabilité lest | ok | | | Longitude (°) | 6°57.502 E |

**Récupération**

| | | | | | |
|---|---|---|---|---|---|
| Largage | 25/10/20 | End recording | | Taille data (Mo) | |
| En surface | 06h19 | Drift | 2020/10/25 08:47:59 | Nb fic data | |
| A bord | 06h48 | Drift value | -9 ms | Tension (vbat) | |
| | | Halt | ok | Pression (pres) | |
| Led av arret larg | | | | Download | |
| Led ap arret larg | | | | SAC | ok |

Page 1

OBS2

# FICHE PROGRAMMATION MicrOBS

**Déploiement**

| | | | |
|---|---|---|---|
| Projet | STR2 | Programmé par | Nabil |
| n°station | OBS2 | Vérifié par | Stéphan |

**identification MicrOBS**

| | | | | | |
|---|---|---|---|---|---|
| N° MicrOBS | 178-043 | Code largage | OEF | canal VHF | 72 (156,625MHz) |
| | | Code arrêt larg | F10 | | |

**Programmation de la plongée**

| | | | | | |
|---|---|---|---|---|---|
| Experiment | STR2 | Sync | 20/10/20 | Tension (vbat) | 16,3 |
| Deployment | OBS2 | Start recording | Immediately | Pression (pres) | 567 |
| Sample | 1 | End recording | Endless | | |
| Channels | 4 | Time release | 25/10/20 23:00 | Filtre | FIR2 |
| Gain | 1/2 | Espace libre (Go) | 8 | Led acq marche | 4 |

**Vérifications fin programmation**

| | | | | | |
|---|---|---|---|---|---|
| Courant on | 288 | Serrage connect | ok | Flash | ok |
| Courant off | 0 | Serrage bouchons | ok | VHF | ok |
| | | Bouchon prise vide | ok | led acq marche | 4 |

**Vérification mise à l'eau**

| | | | | | |
|---|---|---|---|---|---|
| Drapeau | ok | Serrage bouchons | ok | Mise à l'eau (h) | 04h42 |
| Anneau | ok | | | | |
| | | led acq marche | 4 | Profondeur (m) | 1196 |
| Serrage lest | ok | | | Latitude (°) | 79°00.018 N |
| stabilité lest | ok | | | Longitude (°) | 6°56.496 E |

**Récupération**

| | | | | | |
|---|---|---|---|---|---|
| Largage | 25/10/20 | End recording | | Taille data (Mo) | |
| En surface | 06h41 25/10 | Drift | 25/10/2020 08:58:59 | Nb fic data | |
| A bord | | Drift value | -78 ms | Tension (vbat) | |
| | | Halt | ok | Pression (pres) | |
| Led av arret larg | | | | Download | |
| Led ap arret larg | | | | SAC | ok |

Page 1

OBS3

# FICHE PROGRAMMATION MicrOBS

## Déploiement

| | | | |
|---|---|---|---|
| Projet | STR2 | Programmé par | Nabil |
| n°station | OBS3 | Vérifié par | Stéphan |

## identification MicrOBS

| | | | | | |
|---|---|---|---|---|---|
| N° MicrOBS | 200-111 | Code largage | 198 | canal VHF | 72 (156,625MHz) |
| | | Code arrêt larg | E67 | | |

## Programmation de la plongée

| | | | | | |
|---|---|---|---|---|---|
| Experiment | STR2 | Sync | 20/10/20 | Tension (vbat) | 16,14 |
| Deployment | OBS3 | Start recording | Immediately | Pression (pres) | 599,3 |
| Sample | 1 | End recording | Endless | | |
| Channels | 4 | Time release | 25/10/20 23:30 | Filtre | FIR2 |
| Gain | 1/2 | Espace libre (Go) | 8,2 | Led acq marche | 4 |

## Vérifications fin programmation

| | | | | | |
|---|---|---|---|---|---|
| Courant on | 284 | Serrage connect | ok | Flash | ok |
| Courant off | 0 | Serrage bouchons | ok | VHF | ok |
| | | Bouchon prise vide | ok | led acq marche | 4 |

## Vérification mise à l'eau

| | | | | | |
|---|---|---|---|---|---|
| Drapeau | ok | Serrage bouchons | ok | Mise à l'eau (h) | |
| Anneau | ok | | | | |
| | | led acq marche | 4 | Profondeur (m) | 1137 |
| Serrage lest | ok | | | Latitude (°) | 79°00.129 N |
| stabilité lest | ok | | | Longitude (°) | 6°55.872 E |

## Récupération

| | | | | | |
|---|---|---|---|---|---|
| Largage | 25/10/20 | End recording | | Taille data (Mo) | |
| En surface | 07h44 | Drift | 25/10/2020 08:58:59 | Nb fic data | |
| A bord | | Drift value | no | Tension (vbat) | |
| | | Halt | ok | Pression (pres) | |
| Led av arret larg | | | | Download | |
| Led ap arret larg | | | | SAC | ok |

Débranché avant d'avoir effectuer le drift !

Page 1

OBS4

# FICHE PROGRAMMATION MicrOBS

**Déploiement**

| | | | |
|---|---|---|---|
| Projet | STR2 | Programmé par | Nabil |
| n°station | OBS4 | Vérifié par | |

**identification MicrOBS**

| | | | | | |
|---|---|---|---|---|---|
| N° MicrOBS | 200-051 | Code largage | 15C | canal VHF | 72 (156,625MHz) |
| | | Code arrêt larg | EA3 | | |

**Programmation de la plongée**

| | | | | | |
|---|---|---|---|---|---|
| Experiment | STR2 | Sync | 20/10/20 | Tension (vbat) | 16,3 |
| Deployment | OBS4 | Start recording | Immediately | Pression (pres) | 567 |
| Sample | 1 | End recording | Endless | | |
| Channels | 4 | Time release | 25/10/20 23:59 | Filtre | FIR2 |
| Gain | 1/2 | Espace libre (Go) | 8 | Led acq marche | 4 |

**Vérifications fin programmation**

| | | | | | |
|---|---|---|---|---|---|
| Courant on | 286 | Serrage connect | ok | Flash | ok |
| Courant off | 0 | Serrage bouchons | ok | VHF | ok |
| | | Bouchon prise vide | ok | led acq marche | 4 |

**Vérification mise à l'eau**

| | | | | | |
|---|---|---|---|---|---|
| Drapeau | ok | Serrage bouchons | ok | Mise à l'eau (h) | |
| Anneau | ok | | | | |
| | | led acq marche | 4 | Profondeur (m) | 1208 |
| Serrage lest | ok | | | Latitude (°) | 79°00.379 N |
| stabilité lest | ok | | | Longitude (°) | 5°35.733 E |

**Récupération**

| | | | | | |
|---|---|---|---|---|---|
| Largage | 25/10/20 | End recording | | Taille data (Mo) | 7124064 kB |
| En surface | 08h47 | Drift | 25/10/2020 19:11:59 | Nb fic data | |
| A bord | 08h59 | Drift value | -13 ms | Tension (vbat) | |
| | | Halt | ok | Pression (pres) | |
| Led av arret larg | | | | Download | |
| Led ap arret larg | | | | SAC | ok |

Page 1

OBS5

# FICHE PROGRAMMATION MicrOBS

**Déploiement**

| | | | |
|---|---|---|---|
| Projet | STR2 | Programmé par | Nabil |
| n°station | OBS5 | Vérifié par | Stephan |

**identification MicrOBS**

| | | | | | |
|---|---|---|---|---|---|
| N° MicrOBS | 200-082 | Code largage | 17B | canal VHF | 72 (156,625MHz) |
| | | Code arrêt larg | E84 | | |

**Programmation de la plongée**

| | | | | | |
|---|---|---|---|---|---|
| Experiment | STR2 | Sync | 20/10/20 | Tension (vbat) | 16,44 |
| Deployment | OBS5 | Start recording | Immediately | Pression (pres) | 621,2 |
| Sample | 1 | End recording | Endless | | |
| Channels | 4 | Time release | 25/10/20 00:30 | Filtre | FIR2 |
| Gain | 1/2 | Espace libre (Go) | 8 | Led acq marche | 4 |

**Vérifications fin programmation**

| | | | | | |
|---|---|---|---|---|---|
| Courant on | 286 | Serrage connect | ok | Flash | ok |
| Courant off | 0 | Serrage bouchons | ok | VHF | ok |
| | | Bouchon prise vide | ok | led acq marche | 4 |

**Vérification mise à l'eau**

| | | | | | |
|---|---|---|---|---|---|
| Drapeau | ok | Serrage bouchons | ok | Mise à l'eau (h) | |
| Anneau | ok | | | | |
| | | led acq marche | 4 | Profondeur (m) | 1201 |
| Serrage lest | ok | | | Latitude (°) | 79°00.20266 N |
| stabilité lest | ok | | | Longitude (°) | 6°54.49714 E |

**Récupération**

| | | | | | |
|---|---|---|---|---|---|
| Largage | 25/10/20 | End recording | | Taille data (Mo) | |
| En surface | 09:29:00 | Drift | 25/10/2020 19:15:00 | Nb fic data | |
| A bord | | Drift value | 5 ms | Tension (vbat) | |
| | | Halt | ok | Pression (pres) | |
| Led av arret larg | | | | Download | |
| Led ap arret larg | | | | SAC | ok |

Page 1