Fully integrated autonomous uncrewed maritime solution using DriX and FlipiX ROTV

DriX was used with FlipiX Remotely Operated Towed Vehicle (ROTV) to conduct bathymetric, geophysical and UXO surveys fully remotely in La Ciotat Bay (France).

PARTNERS

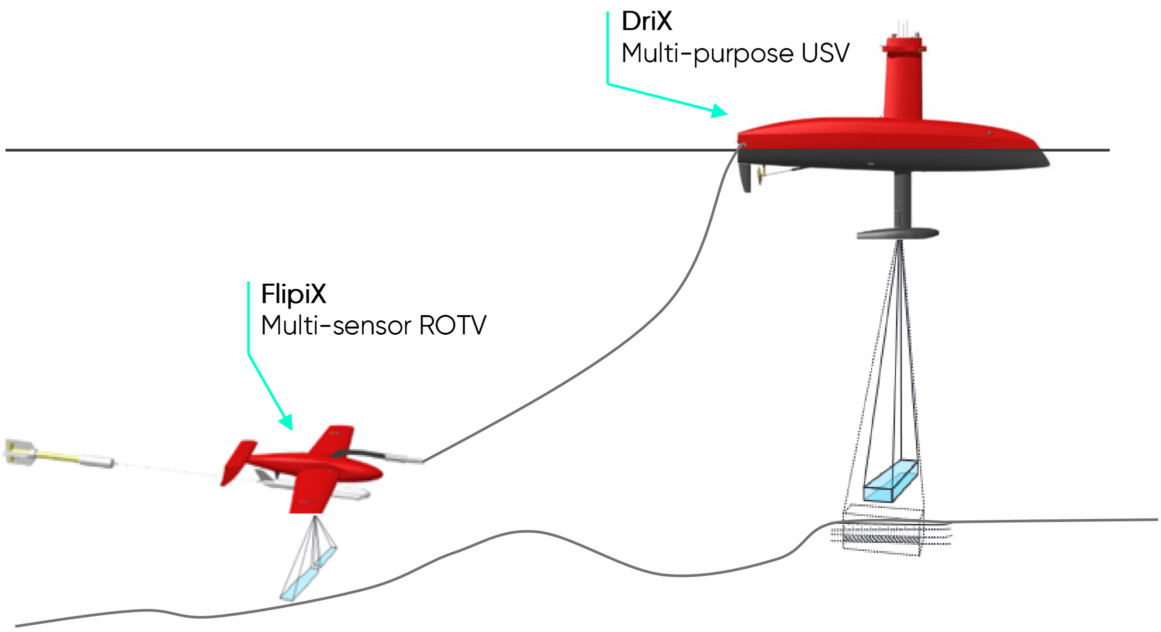
EdgeTech

In November 2022, the Remotely Operated towed vehicle FlipiX (ROTV) was tested with the Uncrewed Surface Vehicle (USV) DriX in La Ciotat to conduct bathymetric and geophysical survey at once. DriX gondola was fitted with a Kongsberg EM2040C multibeam echosounder, an Exail Echoes 3.5K T1 sub-bottom profiler and an Exail GAPS M5 Ultra-Short Baseline (USBL) positioning system. The FlipiX platform, towed by DriX, was conveying an EdgeTech 4205 side-scan sonar (SSS), a G-882 marine magnetometer from Geometrics, an Exail MT9 acoustic transponder and a Valeport MiniSVS sound velocity probe. This survey was performed using Over The Horizon (OTH) capabilities and demonstrated outstanding performance.

▲ Fig.1 DriX trackline during sea trials

1. FlipiX: an actively controlled towed vehicle enhancing navigation control and stability

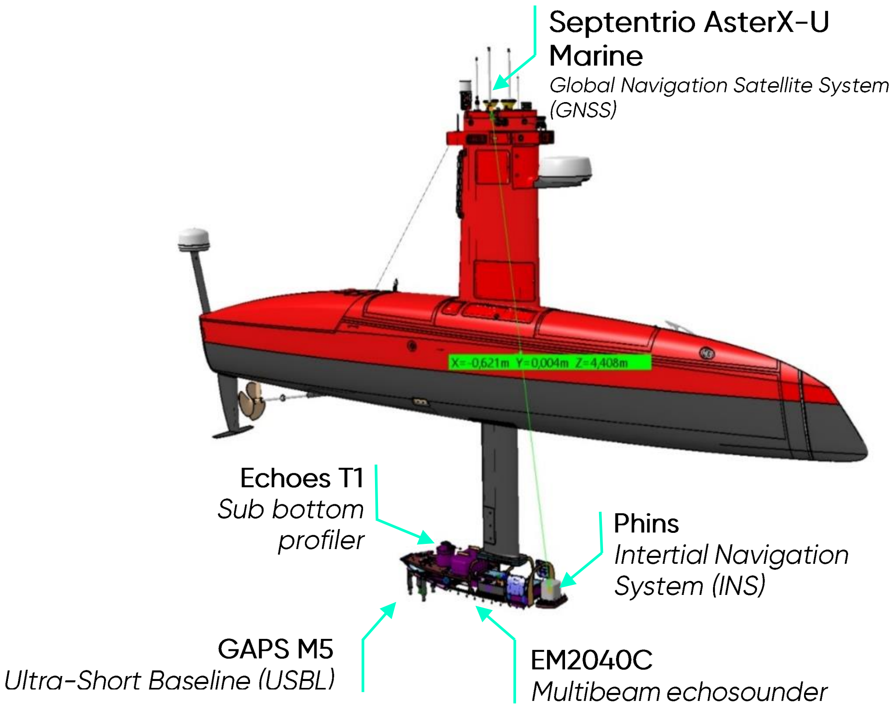
FlipiX is a self-compensated underwater vehicle that can operate a few meters from the seabed for optimum measurement quality. It uses an autonomous mechanism that stabilizes the ROTV by controlling actively the pitch and roll movements and maintains a fix altitude above the seabed. Using a DriX, which remains hydrodynamic at the surface even in severe conditions, and a FlipiX, which is stabilized underwater, provides a combined solution eliminating motion artifacts that are commonly transferred to tow fish by conventional survey platforms. In addition, electrical noise often induced by the winch to adjust the altitude of the tow fish is removed from the equation with FlipiX's navigation self-compensation.



▲ Fig.2 : DriX USV and FlipiX ROTV

2. Combination of DriX and FlipiX for a multi-sensors data acquisition

DriX payload was fitted with a Kongsberg EM2040C multibeam echosounder coupled with a Valeport MiniSVS located at the transducer head to record variations of the sound velocity in real time. The multibeam was operated at 400 kHz, with a DriX navigating at 7 knots allowing to build a 50x50 cm grid by 40 meters deep with an average sounding density of 12 soundings per cell. An Echoes T1 sub-bottom profiler was mounted on the gondola and operated at 3.5 kHz allowing to get a beam aperture of 45° and a vertical resolution of 20 cm. DriX positioning system was delivered by the Inertial Navigation positioning system (INS) coupled with a Trimble GA830 GNSS antenna and a Septentrio AsteRx-U GNSS receiver. Underwater positioning system was provided by the USBL GAPS M5 located on the gondola, with a 200° aperture and a positioning accuracy of 0.5% of the slant range. The DriX diagram below (Figure 3) shows the main survey equipment fitted in the DriX Gondola.

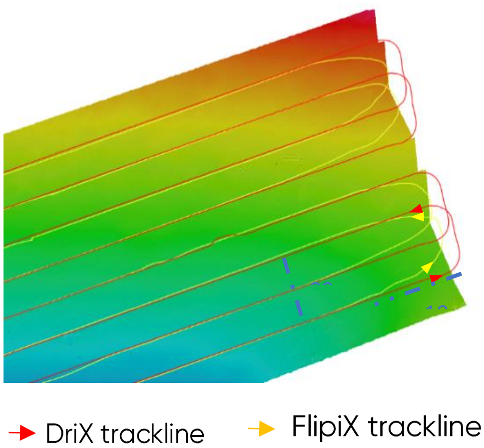


▲ Fig. 3 : Main survey equipment fitted in the DriX Gondola.

FlipiX ROTV was equipped with an Edgetech 4205 Side-scan sonar and recorded both 540 kHz and 850 kHz frequencies. Horizontal and across track beam resolutions reach respectively 0.20 m and 1 cm at 850 kHz by 50 m of water depth. Both recorded frequencies allowed to build a high-resolution mosaic of 10 cm. FlipiX towed a G-882 marine magnetometer from Geometrics. The G-882 is a Cesium Vapor magnetometer that was operated at 10 Hz. It was coupled with calibrated altimeter and depth sensors. A Valeport MiniSVS fitted with a pressure sensor was mounted on the FlipiX allowing to record sound velocity profiles underway while FlipiX diving from the surface to the seabed. FlipiX real-time underwater position was tracked by the MT9 transponder. Interrogation of position was made with a recurrence of 2 seconds.

3. Optimized data acquisition and survey efficiency

The sea trials carried out in la Ciotat in November 2022 demonstrated efficiency in terms of navigation. FlipiX navigated at 4 knots at a constant altitude of 6 metres above the seabed for 3 hours. DriX and FlipiX navigation, entirely controlled automatically, allowed to follow the line plan with very little off-track. Off-tracks can be critical for UXO survey constraints. Figure 5 below shows a superposition of DriX and FlipiX tracklines with small off-track. The average off-track measured for this survey between DriX and FlipiX is 1.1 metres using a 100 meter-long cable.



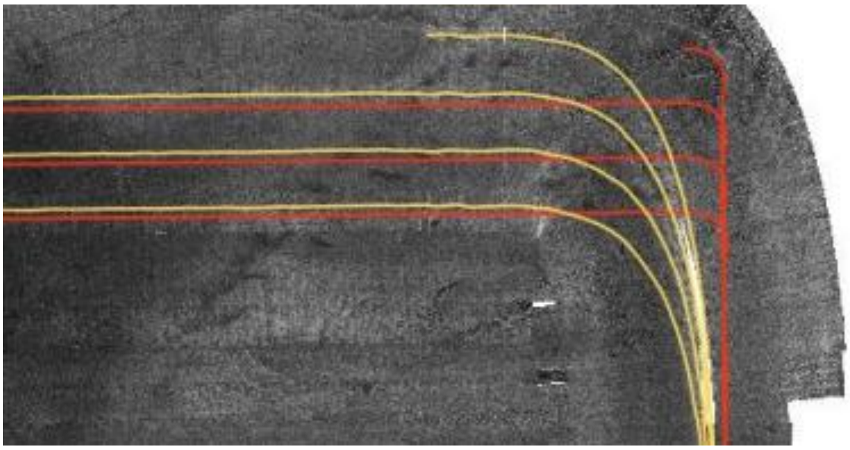
▲ Fig. 5

FlipiX navigation was tested specifically during turns. The constant and active control of the altitude allowed to significantly reduce the lines length-in and length-out. Sharp turns were made possible (>80 m). The duration of the gyration computed was less than 3 minutes following a line spacing of 80 m. Survey statistics are presented in the table below.

Survey statistics	
Mean FlipiX altitude	6 m
Mean DriX and FlipiX speed (Speed over ground)	3.8 knots
Duration of the survey	2 hours 30 min
Kilometres of lines	9,6 km
Average off-track DriX vs FlipiX	1,1 m
Duration of a gyration	3 min
Length of cable out from DriX to FlipiX	100 m

▲ Sea trails statistics

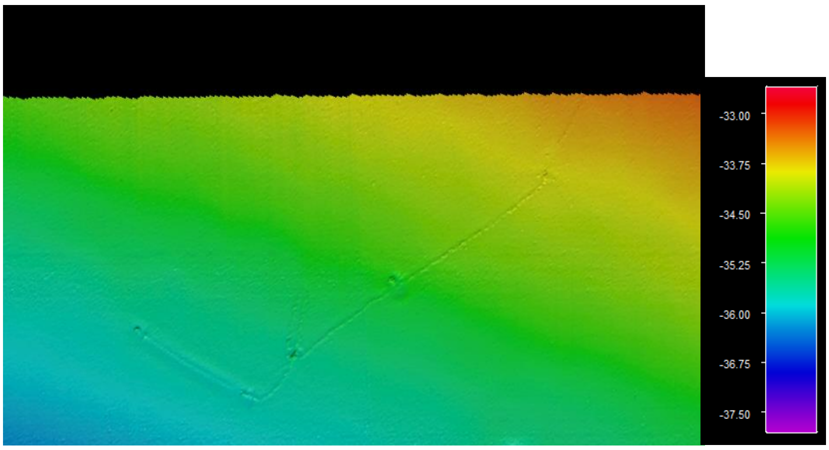
In addition, the stability of the FlipiX platform allowed to record side-scan data during gyration with no drop in the altitude. Figure 6 shows side scan sonar data mosaic (10 cm resolution) during turns.



▲ Fig.6 Recording of Side Scan data during turns

4. <u>DriX and FlipiX : a combined autonomous solution for multi-sensors survey</u>

DriX in combination with FlipiX performed a 3-hours bathymetric and geophysical survey on characteristic surface in La Ciotat. The survey was conducted at 7 knots with no compromise in the data quality and allowed to identify small objects such as chains laying on the seabed. Figures 7 below show a 50 cm resolution bathymetric grid model with features on the seabed.



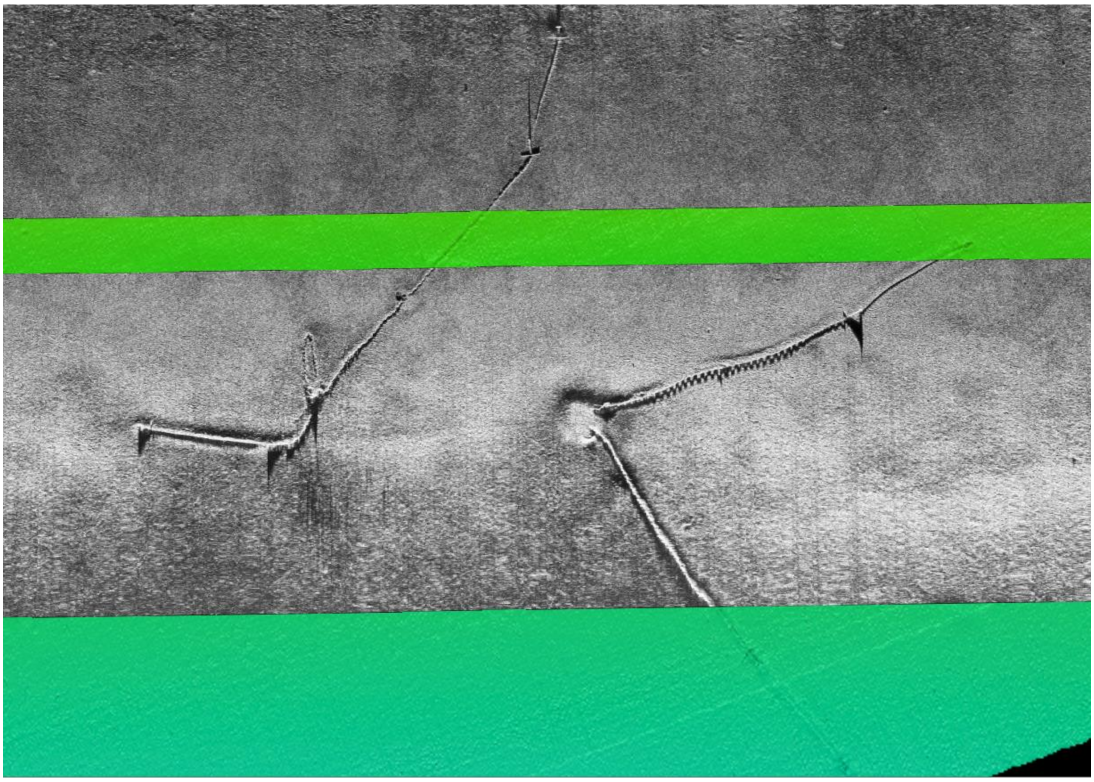
▲ Fig. 7 : 50 cm bathymetric data showing anchors chains and small blocks

The bathymetric data set was compared to a reference surface located in la Ciotat. The reference surface is a square area of 400x400 m, by 40 meters deep. The grid model used for comparison was a 25x25 cm grid. Average difference computed was 1 cm between the post processed grid and the reference surface.

Statistics for a 50x50 cm bathymetric grid	
Average depth (meter/ref to LAT)	34 m
Minimum depth (meter/ref to LAT)	26 m
Maximum depth (meter/ref to LAT)	40 m
Mean standard deviation	0.03 m
Soundings density grid (cell number)	12
Difference between Post processed surface (25 cm) / Reference surface (25 cm)	0.01 m

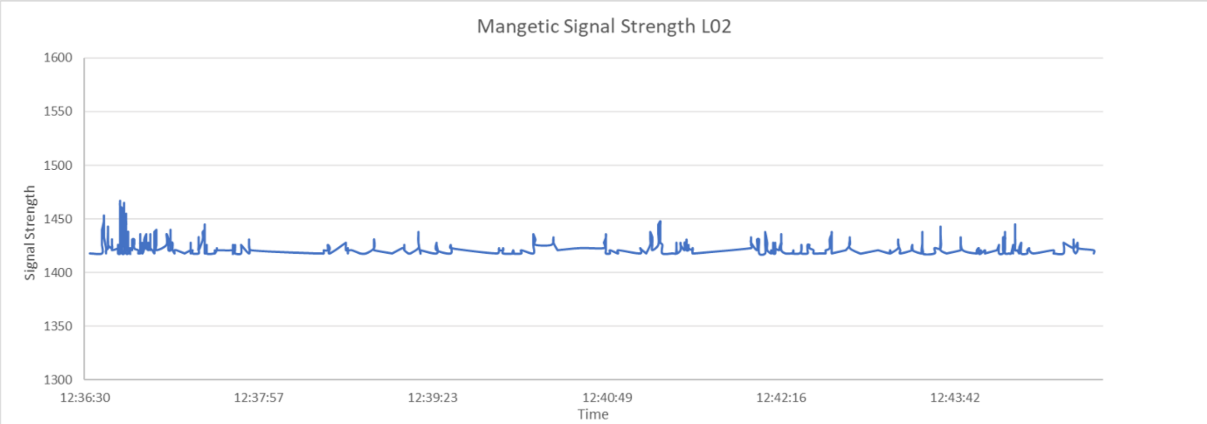
▲ Sea trials statistics

The survey area run across features such as anchor blocks and metallic chains used for positioning check comparison between sensors.
Figure 8 below shows overlapping bathymetric grid (50 cm) and high-resolution side-scan sonar mosaic (10 cm). Features such as chains can easily be observed on both datasets.



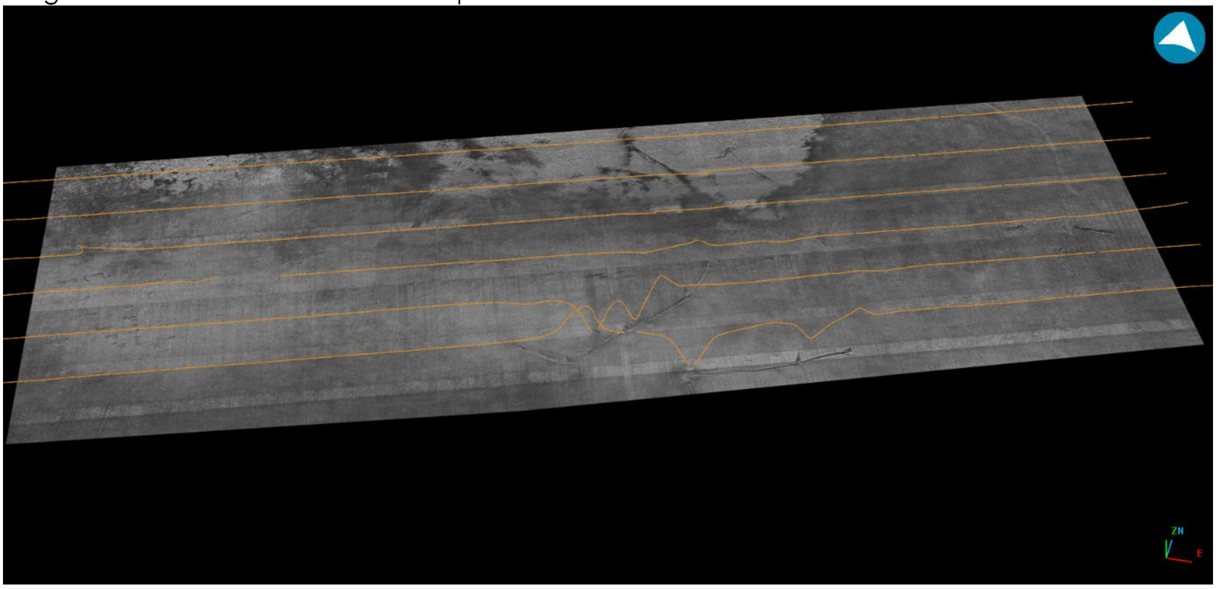
▲ Fig.8: Overlapping side scan and bathymetric data

The ambient magnetic field was recorded constantly during survey operations at a frequency of 10 Hz. The magnetometer demonstrated a very low level of noise. Figure 9 below shows the signal strength on a survey line with low magnetic field variations (see table 4 below).

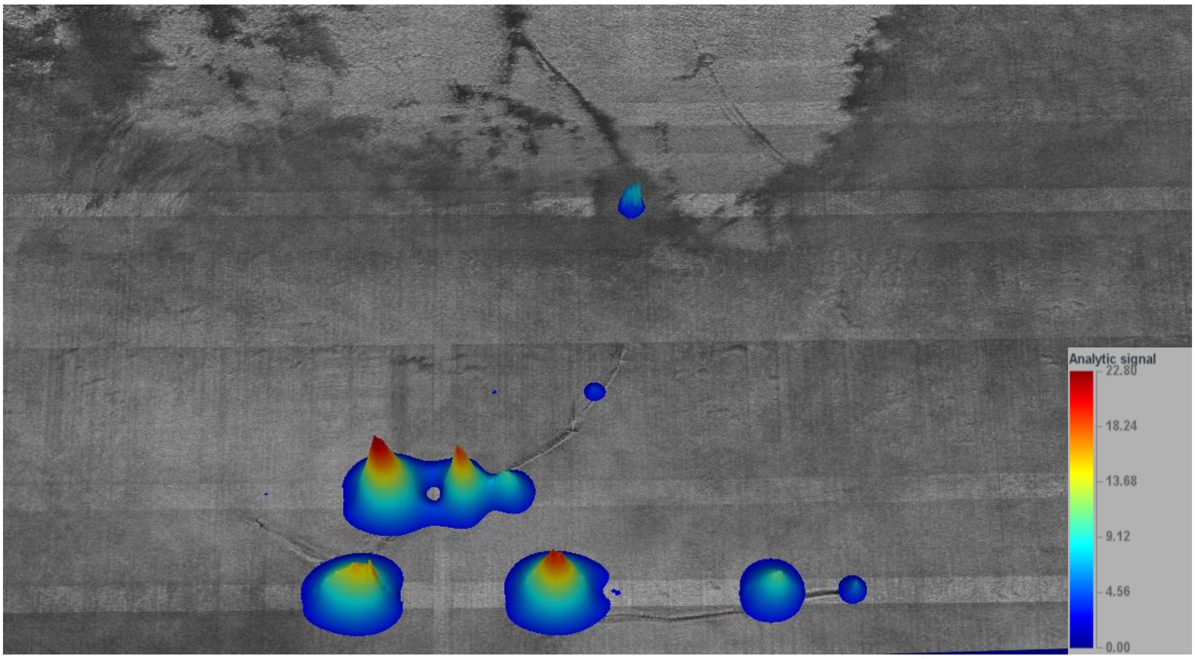


▲ Fig 9 : Magnetometer signal strength

Magnetometer data was acquired simultaneously showing correlation in the objects position with bathymetric data set and side-scan sonar data set. Figures 10 and 11 below show the magnetic residual field charted on top of the side-scan sonar mosaic.

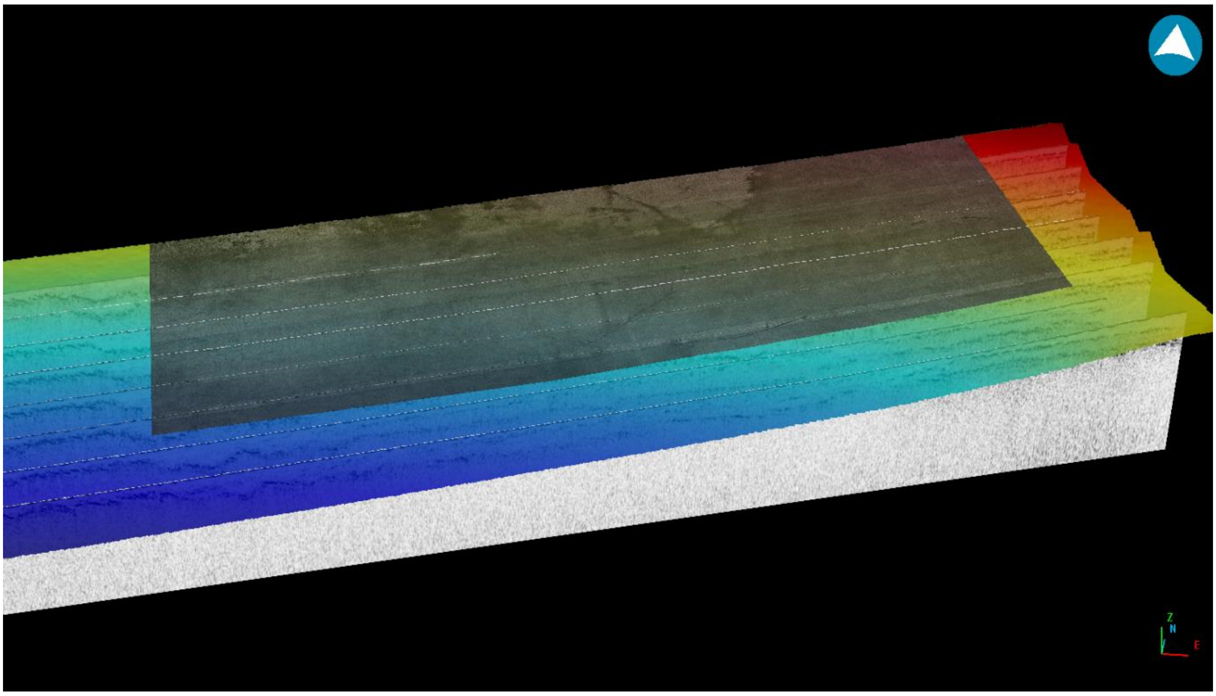


▲ Fig.10 : side scan image with magnetic field curves overlapped

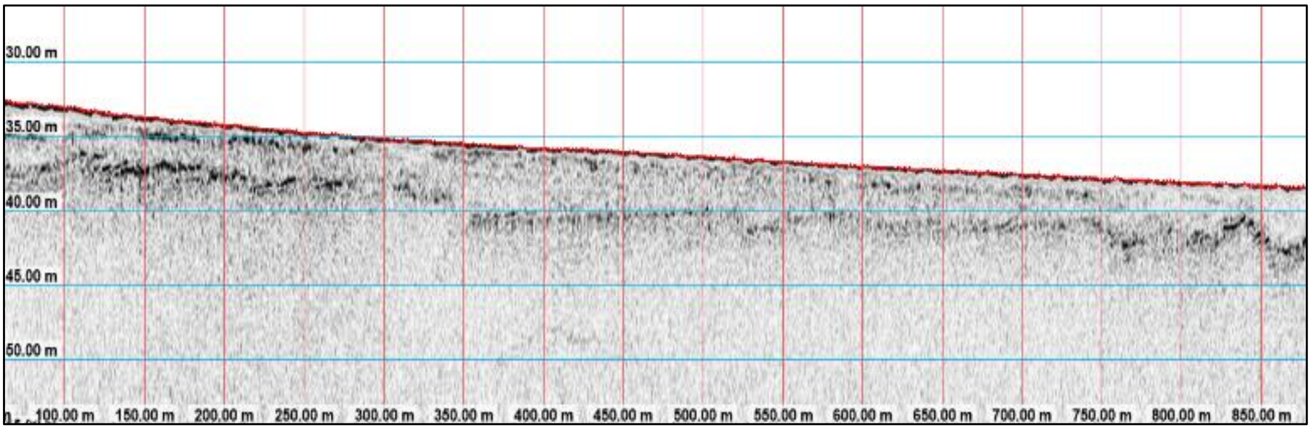


▲ Fig.11 : Side scan image with gridded magnetic anomaly

In addition to side scan sonar imagery, bathymetric and magnetic measurements, the sub-bottom profiler acquired data to assess the geology of the seabed with profiles spread-out across the area (Figures 12 and 13).



▲ Fig.12 side scan, bathymetry and subbottom merged together



▲ Fig.13 sub-bottom imagery