AUV-based Magnetometry

Overview

The integration of submersible magnetometers into GEOMAR's Girona 500 hovering AUVs renders the possibility of conducting fully autonomous geomagnetic surveys underwater. While the most representative application of this system is the detection and localization of underwater munitions (UneXploded Ordnance / UXO), the spectrum of applications covers the monitoring of critical infrastructure like cables, pipelines, harbors and sea lanes, and other scientific fields like underwater archeology. For ground-truthing purposes, the AUV is equipped with a high-resolution camera.

AUV

AUVs (Autonomous Underwater Vehicles) usually operate beyond the control of any piloting personnel while conducting preprogrammed missions. They navigate autonomously and therefore provide an efficient method to conduct fast and precise surveys. AUVs are usually relatively small, easily transportable, and independent from their mother vessel which can perform other tasks during AUV missions. In comparison to vessel-towed systems, AUV-based surveys provide a much higher spatial precision. The GEOMAR Helmholtz Centre for Ocean Research Kiel owns two Girona 500 hovering AUVs called "Anton" and "Luise", developed at the Underwater Robotics Laboratory of the University of Girona, Spain. They may be adapted for different types of seafloor surveys like highly specialized inspection and intervention tasks. The hovering capabilities of these AUVs allow them to maintain a fixed position or to precisely navigate at very low velocities and altitudes.

Magnetometers

The utilized magnetic sensors are four FGM3D/100 UW II 3-axis fluxgate magnetometers from SENSYS GmbH. Each magnetometer is sampling three spatial components at a sampling rate of 200 Hz yielding a data point spacing of 2.5 mm into the direction of travel at a velocity of 0.5 m/s. The geometry layout allows for the measurement of all three spatial magnetic gradients. The combination of these gradients yields the 3D analytic signal, a derived value that exhibits maxima over magnetization contrasts and that determines the outlines of magnetic sources. The rigid construction that holds the magnetometers (see Figure 1) suppresses spatial errors that towed systems usually produce.

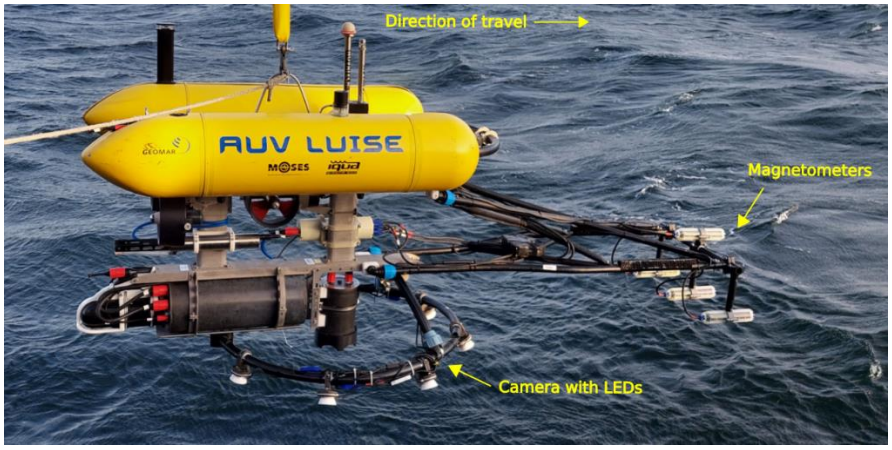

Figure 1: GEOMAR's Girona 500 AUV "Luise" with four submersible magnetometers and a camera system incl LEDs.

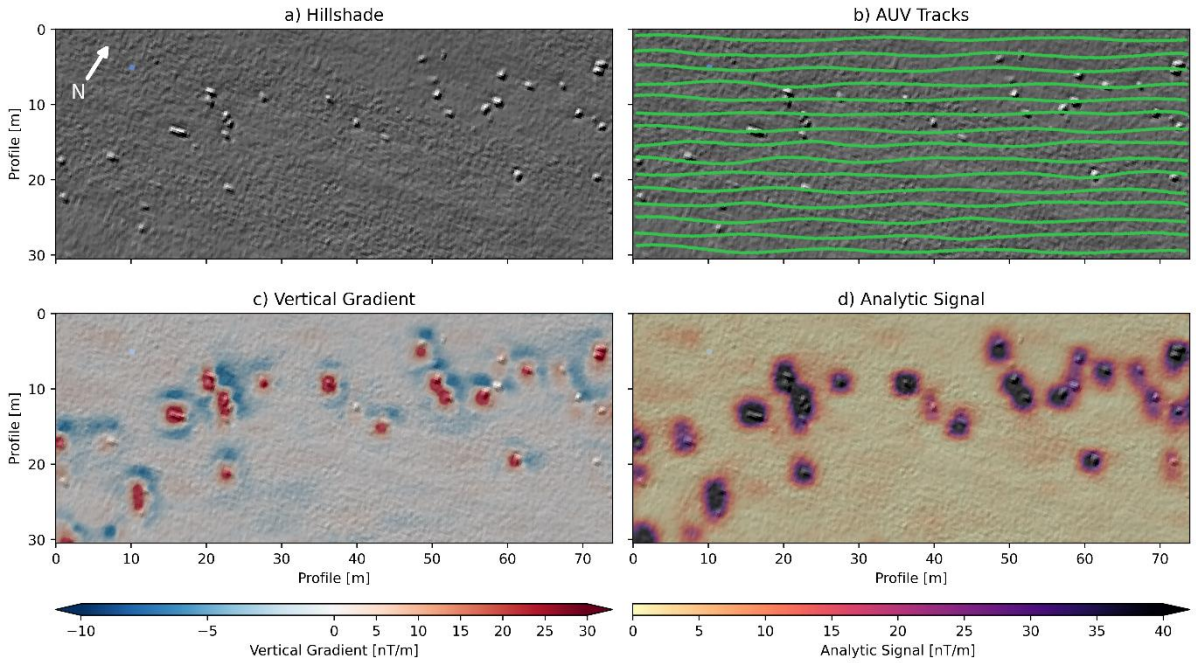

Figure 2: Bathymetric, navigational, and magnetic data of an AUV mission at Kolberger Heide from October 2021. (a) Hillshade derivative of the bathymetry, (b) AUV tracks with 2 m line spacing, (c) vertical magnetic gradient, and (d) analytic signal. The bathymetric data were acquired during a previous MBES survey.

Exemplary Results

When operating mission grids with a comparably narrow line spacing of 1-3 m, 2D magnetic results of the survey area can be calculated. Figure 2 shows a 73 × 31 m² section of an AUV mission at the munitions dumpsite "Kolberger Heide" near Kiel, Germany. The underlying hillshade of the bathymetry shown in Figure 2a was acquired during a previous multibeam echosounder (MBES) survey. The acoustic data indicates dozens of potential UXO targets of different shapes and sizes on the seabed in that area. After the survey, all objects generated magnetic signals in the magnetometers (Figure 2c+d) and are therefore very likely UXO. Figure 2b shows the cropped AUV track lines (green) that were considered for calculating the magnetic 2D raster data (Figure 2c+d). Data that were recorded during turning maneuvers at the end of each line were omitted because they are usually too noisy. In this example, the mission's line spacing was 2 m. The total mission time for 16 survey lines of 80 m length at 0.5 m/s (including turning maneuvers) was approximately 1 hour.

CONMAR

Within the scope of the CONMAR project on its way in making assessments of munition's remediation approaches and to advance the scientific understanding of the role and fate of marine munitions in the environment, AUV-based magnetic measurements assist in acquiring detailed information on the distribution and condition of munitions in German waters. In comparison to the majority of acoustic methods that can only detect objects which are prominent on the seafloor, magnetic surveys can also detect UXO that are buried a few meters in the seabed.

Further information

Project SAM (Smart AUV-based Magnetics): http://www.sam-project.eu

Seidel, M., Frey, T. & Greinert, J. (2023) Underwater UXO detection using magnetometry on hovering AUVs. *Journal of Field Robotics*, 40, 848–861. http://doi.org/10.1002/rob.22159