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A hydrospatial research centre with an international scope

An article by MOHAMED ALI CHOUAER and GUILLAUME LABBÉ-MORISSETTE

CIDCO, a non-profit organisation created in 2002, is at the forefront of marine, hydrographic and hydrospatial sciences. For the past 20 years, the CIDCO team has allowed the only French-speaking hydrography research centre in America to work on numerous projects (international and local) for ministries, municipalities, industries, private companies, educational institutions and many other renowned partners. We also developed hydrographic equipment and software to facilitate the acquisition and interpretation of underwater data. Our mission is to modernise hydrography. You will learn how we offer an internationally certified S-5 Category B training programme, how we use LiDAR and sonar for autonomous navigation and infrastructure inspection, and how crowdsourced bathymetry (CSB) contributes to the global seabed mapping effort.

CIDCO | distance learning | Category B | crowdsourced bathymetry | MASS | habitat map
CIDCO | enseignement à distance | Catégorie B | bathymétrie participative | MASS | carte des habitats
CIDCO | Fernstudium | Category B | Crowdsourced Bathymetry | MASS | Habitatkarte

CIDCO, une organisation à but non lucratif créée en 2002, est à la fine pointe des sciences marines, hydrographiques et hydrospatiales. Depuis 20 ans, l'équipe du CIDCO a permis au seul centre de recherche francophone en hydrographie d'Amérique de travailler sur de nombreux projets (internationaux et locaux) pour des ministères, des municipalités, des industries, des entreprises privées, des institutions d'enseignement et bien d'autres partenaires de renom. Nous avons également développé des équipements et des logiciels hydrographiques pour faciliter l'acquisition et l'interprétation des données marines. Notre mission est de moderniser l'hydrographie. Vous apprendrez comment nous offrons une formation S-5 catégorie B certifiée, comment nous utilisons le LiDAR et le sonar pour la navigation autonome et l'inspection des infrastructures, et comment la bathymétrie participative (CSB) contribue à l'effort global de cartographie des fonds marins.

CIDCO, eine 2002 gegründete gemeinnützige Organisation, steht an der Spitze der Gewässerwissenschaften sowie der Hydrographie. In den letzten 20 Jahren hat das Team des CIDCO als einziges französischsprachiges Forschungszentrum für Hydrographie in Amerika an zahlreichen (internationalen und lokalen) Projekten für Ministerien, Gemeinden, Industrie, Privatunternehmen, Bildungseinrichtungen und viele andere renommierte Partner gearbeitet. Wir haben hydrographische Geräte und Software entwickelt, um die Erfassung und Auswertung von Unterwasserdaten zu erleichtern. Unser Ziel ist es, die Hydrographie zu modernisieren. Sie erfahren, wie wir ein international zertifiziertes Trainingsprogramm nach S-5 Kategorie B anbieten, wie wir LiDAR und Sonar für die autonome Navigation und die Inspektion von Infrastrukturen einsetzen und wie die Crowd-Sourced Bathymetry (CSB) zur globalen Kartierung beitragen kann.

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CIDCO presentation

The Centre for Interdisciplinary Ocean Mapping Development (CIDCO), located in Quebec (Canada), is a hydrospatial R&D organisation working on the development of technologies for the acquisition, management and graphic representation of marine spatial data. CIDCO is a non-profit organisation (established in 2002) at the forefront of marine, hydrographic and hydrospatial sciences, serving the R&D needs of institutions and industry.

CIDCO has developed an international partnership network (particularly with France: ENSTA Bretagne, Shom, Ifremer, iXblue, Hytech Imaging, Compagnie National du Rhône CNR, Énergie de France EDF, etc.) and is an active member of the Canadian Coastal Ocean Mapping Research and Education Network (COMREN) in addition to being recognised by Fisheries and Oceans Canada as a Canadian Champion for the United Nations Decade of Ocean Sciences for Sustainable Development (2021–2030).

Over the past 20 years, the CIDCO team, in addition to offering world-renowned S-5 Category-B training, has enabled the operational research and development centre to work on numerous projects for ministries, municipalities, industries, pri-

vate companies, educational institutions and many other renowned partners. The team also develops and transfers hydrographic equipment and software such as HydroBall®, HydroBlock®, HydroTom, Depthstar and OpenSideScan to facilitate the acquisition and interpretation of underwater data with institutional and commercial partners.

Among its many achievements, CIDCO has proposed to integrate new inspection methods combining sonars and laser scanners into autonomous navigation technologies in order to carry out the inspection of all types of partially submerged infrastructure at lower costs, in complete safety and in a sustainable manner. In recent years, CIDCO developed high-precision calibration algorithms, which have solidified its reputation as a leader in automated metrological solutions. These include the auto-calibration of boresight angles, of inter-sensor latency and of lever arms. Currently, CIDCO is developing intelligent algorithms allowing either autonomous or semi-supervised navigation in complex environments, such as ports and harbours. This will allow survey vehicles to maintain optimal coverage while avoiding static and dynamic obstacles within the active port dynamics, increasing both the safety and efficiency of the survey work.

A certified S-5 Category-B training

Parallel to the excellence of its applied research, CIDCO is also known for its vocational training in hydrographic sciences, with a unique feature: the possibility to follow a Category-B training at distance. It is the only institution in North America offering a recognised course in hydrographic surveying in both French and English languages. This course aims to provide theoretical foundations and practical field experience that enables future hydrographers to execute hydrographic surveys, monitor and evaluate survey data quality in accordance with the latest IHO standards. The targeted audience for this course constitutes people with at least a technical diploma in geomatics, surveying, civil engineering, or related fields. Many of these people are those with a significant experience in hydrography with no certification or recognition who now see the need to follow a certified training. The training allows graduated students to work as hydrographers on large survey operations such as nautical charting surveys, offshore surveys or on small survey units, utilised for ports, coastal engineering, inland waters and surveys launches in support of a large-scale survey operation.

CIDCO is committed to capacity building, not only in Canada but also worldwide. It is with this in mind that CIDCO has been developing its expertise in distance learning since 2016. Indeed, well before the Covid-19 pandemic, CIDCO's online training course »Course in Hydrographic Surveying« has been offered as e-learning modules, making this course accessible to students from all around the world. Over the past six years, 33 students from 18 different countries have completed the online programme (Fig. 1), with the constant support of the CIDCO's tutors that can be found with a few clicks on the other end of the mouse.

Fig. 1: Origin of students who have participated in the CIDCO Cat-B programme since 2016

The theoretical part of the course is given as an e-learning formula (Fig. 2). The online platform is among the best Learning Management System (LMS) on the market. It enables the management of course activities, post course materials and electronic documents. This type of format makes the teaching resources and materials accessible to students any time from any computer anywhere in the world. In addition, this gives students the opportunity to complete the online activities at their

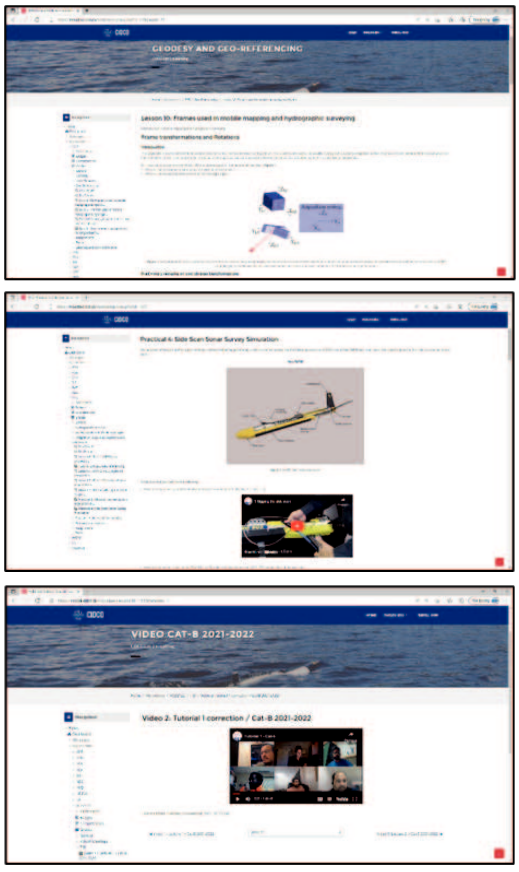

Fig. 2: CIDCO e-learning platform

Fig. 3: Cat-B students performing different hydrographic tasks

own pace without the same pressures as in-class activities.

The theoretical part is followed by an in-person practical session (Fig. 3), a seven-week field session on site, in Rimouski, Canada, to put into practice the theory and knowledge all through a well-defined hydrographic survey project. This part is critical and important not only to put in practice learning and ensure qualification before graduation, but also to establish great invaluable relationships between participants from around the world, creating a rich international professional and personal network for the future.

Applied research projects

CIDCO is incorporated as a non-profit organisation, which gives it a great deal of independence and flexibility in its action plan. Among the many projects on which it has succeeded in distinguishing itself, four are summarised below.

First Nations – Trusted crowdsourced bathymetry and capacity building in British Columbia

The International Hydrographic Organization (IHO) defines crowdsourced bathymetry (CSB) as depth measurements from vessels, collected using standard navigation instruments, while engaged in routine maritime operations (https://iho.int/en/csbwg). Canada has been looking at developing a reliable approach, based on collaborative data collection, to address the enormous challenge of collecting hydrographic data in all remote areas of the country where bathymetric data are lacking.

As part of a previous crowdsourced bathymetry (CSB) pilot project in the northern region of Canada, participatory bathymetry systems (HydroBall® and HydroBlock®) were developed by some COMREN members for data acquisition, processing and dissemination. These systems were specifically developed for use by non-specialists.

The project that CIDCO with COMREN partners have been working on focuses on building the capacity of First Nations communities to engage, involve and participate in the collection of hydrographic data to ensure safe and efficient navigation in remote areas of the central coast of British Columbia. The data can also be used to characterise the marine environment. Training and knowledge transfer to the Nanwakolas Council and its member First Nations communities was provided in the summer of 2022 in order to collect the data according to national and international standards.

As a result of the lessons learned from this innovative project, the CIDCO team upgraded the participatory bathymetry systems, expanded its

Fig. 4: Hydroball® on the field

capacity for CSB and facilitated data dissemination to the Nanwakolas Council and its members in First Nations communities in British Columbia. This was an opportunity to co-design new models involving stakeholders in all its operations with the intention of integrating, not replacing, the knowledge of the Nanwakolas Council and its First Nations members about hydrospatial conditions and safety at sea in their regions.

Given that only 23.4 % of the world's oceans have been surveyed to date and to meet the challenges of initiatives such as Seabed 2030, several technologies have been developed and used. The technology proposed by CIDCO and its partner M2Ocean® to meet this challenge was a low-cost system that allows for the recording of depth and position data on any type of vessel. In the spring of 2021, a project to develop this type of system was completed by the CIDCO team. The project developed a prototype of an improved version of the HydroBall® (Fig. 4). The original HydroBall® is a compact tractable bathymetric survey system. The main benefit of the HydroBall® is its capacity of being deployable without having to adapt the supporting vessel. The objectives of this project were to improve the technological capabilities of the HydroBall® in order to increase its number of applications, to add intelligent functions and to use artificial intelligence for the classification of seabed substrates.

CIDCO and M2Ocean are already part of the CSB expert committees and have already been approached by three national hydrographic services (Canada, the United States and Denmark) to request an intelligent and robust product that they can put in the hands of operators in their jurisdictions.

The HydroBall® and HydroBlock® are compact systems that integrate GNSS, an inclinometer and a single-beam echo sounder. Bathymetric soundings taken with these systems meet IHO standards (S-44 Order 1b).

Enabling MASS technologies

The emergence of Maritime Autonomous Surface Ships (MASS) represents a unique opportunity in terms of instrumentation and collaborative hydrospatial data acquisition techniques. This project aims to exploit Trusted Collaborative Bathymetric Acquisition (TCSB) techniques to build an operational framework to facilitate the implementation of MASS technologies.

CIDCO is building on the concept of participatory bathymetric data collection, using the opportunity of commercial vessels, by equipping large vessels with bathymetric data loggers (Hy-

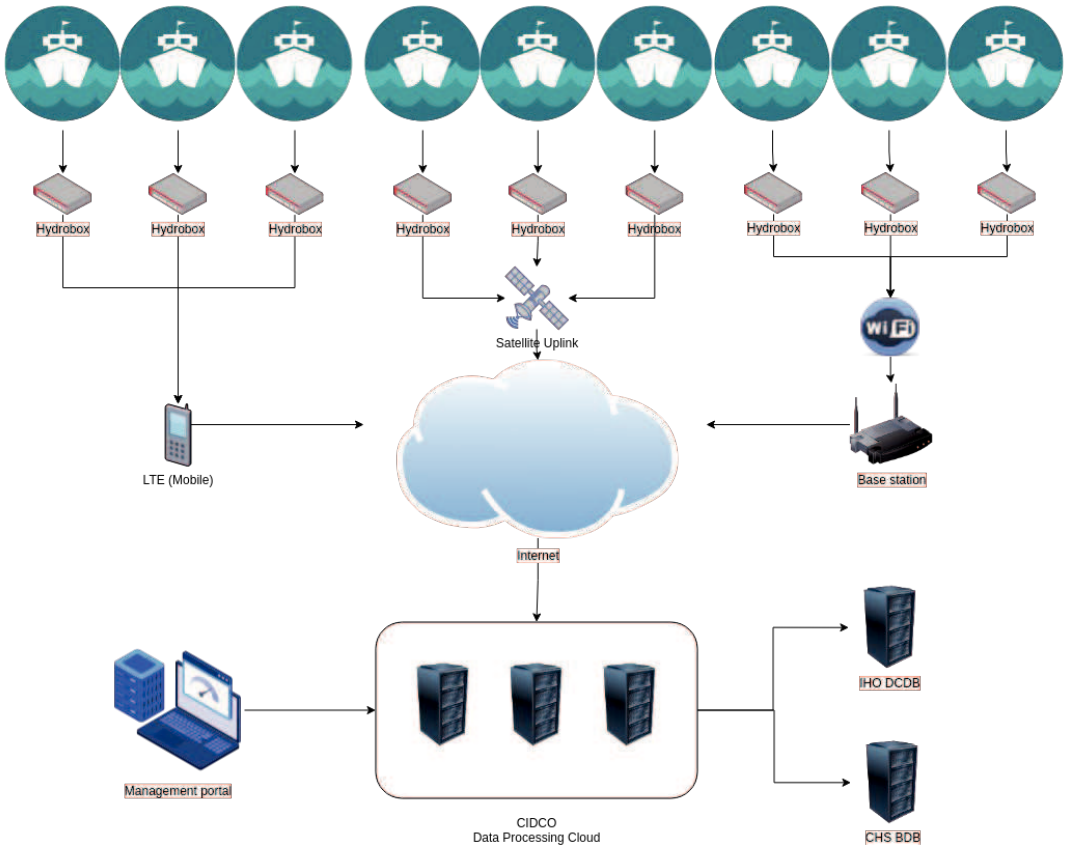

Fig. 5: CIDCO Trusted Collaborative Bathymetric Acquisition (TCSB) system

droBlock®) and installing data transfer stations at strategic locations (Fig. 5). A prime example of the use of such technologies is in the St. Lawrence Seaway. The requirement of up-to-date safe navigable depth in the St. Lawrence Seaway can be fulfilled by allowing raw data to be automatically collected from ships and sent to a data processing cloud that transforms raw bathymetric data into quality products suitable for active monitoring of the St. Lawrence Seaway. This data can also further be integrated into Canadian Hydrographic Service (CHS) data products and services. The first vessel to be equipped with this system is the *Bella Desgagnés*, a passenger transport and supply ship for the lower North Shore owned and operated by Relais Nordik inc. (Fig. 6). This system makes it possible, in real time when the ship is in areas covered by a cellular network, to retrieve the ship's bathymetric data and send it to the cloud.

Fig. 6: The *Bella Desgagnés* with Hydroblock®

Reducing the threat of ghost fishing in snow crab fishing areas by retrieving abandoned traps from the seafloor

For the last four years, CIDCO in collaboration with Merinov, an R&D centre in fisheries and aquaculture, has been working to find a solution to reduce the threat of entanglement and bycatch of species at risk by conducting a recovery campaign of lost snow crab traps in the Gulf of St. Lawrence in the areas prioritised by the project team. CIDCO developed a solution using multibeam data and artificial intelligence (AI).

CIDCO aims to consolidate the evolution of the technological tools developed within the project (Fig. 7) and to validate them in the field. Thus, a second generation of AI algorithms has been programmed in order to make the most of the data collected during the sea trips to train an artificial neural network in order to detect the fishing gears (Fig. 8). New partnerships were established in order to augment the database of acoustic images of lost traps. For example, a collaboration with the CERMIM (Centre de recherche sur les milieux insulaires et maritimes) has allowed the

Fig. 7: Echoboat and AUV for automatics crab traps detection

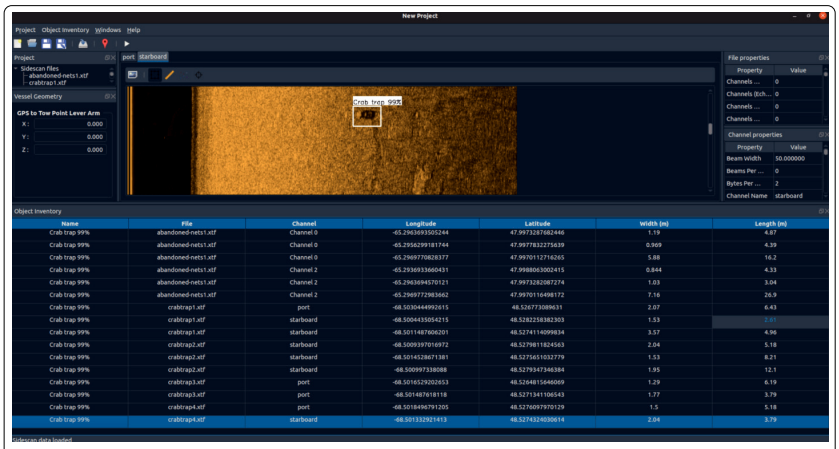

Fig. 8: Crab trap detected by the CIDCO algorithms

addition of nearly 3392 new images and 601 new traps.

This improvement has produced a detection technology that is more robust and less vulnerable to the calibration parameters of the devices, in comparison with the method using computer vision. In addition, the integration of additional data sets to the CrabNet (Compositionally-Restricted Attention-Based Network) system has allowed us to improve the queries performed and to optimise the selection of search areas according to strategic parameters: mammalian frequentation, density of spatial distribution of lost fishing gear, matching lost fishing gear, match lost and recovered gear and generate optimal recovery routes.

Particular attention was paid to validate the process with end users through a test trip with the ACPG (Association des capitaines-propriétaires de la Gaspésie), an association of fishermen and partner in the project. This allowed further customisation of the tool to meet the needs and fulfil the specifications dictated by the end-users.

Automatic classification of benthic habitats using machine learning over sparse 3D point clouds on the North Shore of the Saint-Lawrence Seaway, Canada

According to the Organisation for Economic Co-operation and Development (OECD), the ocean economy will reach 3 trillion dollars by 2030. Ironically, almost 90 % of the world's oceans are not mapped to modern standards. In the spirit of increasing our knowledge of the oceans, benthic habitat mapping has become a necessity with very high stakes, with many countries, notably Canada, engaging in massive benthic mapping campaigns (Proudfoot et al. 2020).

While the world requires more data-driven decision-making to ensure proper sustainable stewardship of natural resources on one end, the efficiency requirements of commercial and industrial ventures have never been higher. As such, efficient technologies are required to adequately map out the benthic zones. Of particular economic interest are geomorphometric methods such as the ones described in a land survey context by Hackel et al. (2016), and shown to be applicable in a hydrographic context by Lecours et al. (2016). With the knowledge that the methods can be applied in a hydrographic context, CIDCO improved on the random-forest methods described in Hackel et al. (2016) and provided a comparative analysis of several machine-learning algorithms applied on several multibeam echo sounder surveys conducted on the North Shore of the Saint-Lawrence River.

The method relies on classifying each sounding based on geomorphometric features computed on its neighbourhood. Using ground-truthing data from Fisheries and Oceans Canada (DFO), a training set of soundings was obtained that can be used to train various machine learning models which can subsequently be used to classify out-of-band data. The bulk 80 % was used to train the models, and the remaining 20 % to assess the quality of the models. Fisheries and Oceans Canada (DFO) has developed a dictionary of underwater habitats, with data acquired at 1000 ground truthing stations (Fig. 9). Available for each station are longitude and latitude, the dominant three bottom substrates, and vegetation type if applicable.

Fig. 9: DFO ground truthing stations in the Saint-Lawrence River

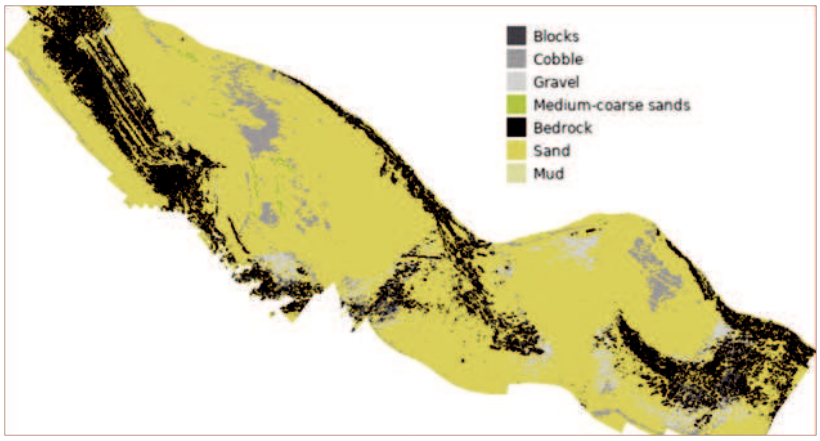

Fig. 10: Distribution of habitat classes in Baie-des-Anglais

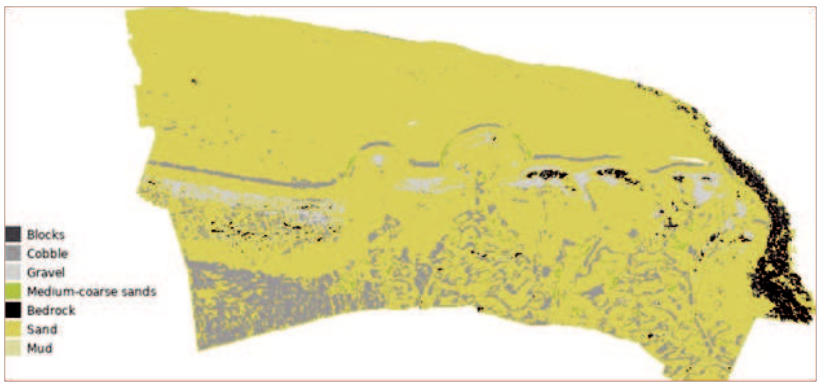

Fig. 11: Distribution of habitat classes in Franquelin

While the categorisation could be optimised to improve precision, it was decided to preserve the domain-specific information and format that the employees of the Government of Canada are used to in order to generate directly transferable results.

In order to generate the training data, the ground truthing stations' data has been cross-referenced with the MBES data in order to get a neighbourhood large enough to compute the feature vector for every ground station point. Habitat classes were derived from substrate particle size nomenclature provided by DFO in order to generate products meant to be helpful to biologists. Namely, bedrock, blocks, cobble, gravel, medium-coarse sands, sand and mud classes were found.

By running the model on each MBES data set, a fully classified data set was obtained which can be readily plugged into any GIS software, in this case QGIS, to generate habitat maps. Fig. 10 and Fig. 11 show model-generated maps.

As such, the technique is quite useful to instantly map out a geological phenomenon that would require many hours by an expert. This information can be leveraged in process automation in many fields, by providing bottom type information to a superior logic layer. This could open doors in improving resource monitoring in biology, searching for specific geological formations in oil and mining industries, and many more. The use of a sparse DTM implies that the technique can be readily generalised to data coming from a large variety of sensors such as multibeam echo sounders, aerial bathymetric lidar, satellite-derived bathymetry, and many more. Further research could easily leverage more than one remote sensing method to improve this technique.

Conclusion

As long as we have not succeeded in mapping all the rivers and oceans of the planet, innovation in hydrography and the hydrospatial domain will always be necessary in order to accelerate and simplify the processes. The existence of research centres is therefore essential in this field. By helping or participating in the development of projects for institutions, ministries, private companies, governments and all other research centres around the world, CIDCO has succeeded in building its credibility and reputation over the past 20 years. Whether it is for the creation of autonomous vehicles with collision avoidance, LiDAR autocalibration, hydrographer training, collective bathymetry or any other challenge, our team's reactivity and taste for innovation allow us to respond to any challenge. //

References

Hackel, Timo; Jan D. Wegner; Konrad Schindler: Fast semantic segmentation of 3d point clouds with strongly varying density. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences. DOI: 10.5194/isprs-annals-III-3-177-2016

Lecours, Vincent; Margaret F. J. Dolan; Aaron Micallef; Vanessa L. Lucieer (2016): A review of marine geomorphometry, the quantitative study of the seafloor. Hydrology and Earth System Sciences. DOI: 10.5194/hess-20-3207-2016

Proudfoot, Beatrice; Rodolphe Devillers; Craig J. Brown et al. (2020): Seafloor mapping to support conservation planning in an ecologically unique fjord in Newfoundland and labrador, Canada. Journal of Coastal Conservation. DOI: 10.1007/s11852-020-00746-8