Explorer AUV missions in coastal Newfoundland

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ABSTRACT

The Marine Environmental Lab for Intelligent Vehicles (MERLIN Lab) at Memorial University of Newfoundland (MUN) operates a survey class autonomous underwater vehicle (AUV) available for scientific research within a wide range of disciplines. The *MUN Explorer* is 4.5 meters in length, 0.69 meters in diameter, weighs 650 kg and displaces 660 kg. This International Submarine Engineering Ltd. (ISE) Explorer class vehicle has the capacity to handle 200 kg of scientific payload. With a range of up to 100 km at speeds of up to 2.5 m/s and depths to 3000 metres, the vehicle is ideal for environmental surveys where bathymetric and mapping sonar, physical and chemicals sensors, cameras and acoustic devices are carried. The paper focuses on the capabilities of the *MUN Explorer AUV* and plans to build collaborative projects. Data will be presented on vehicle performance during habitat mapping in coastal Newfoundland.

Habitat mapping was conducted with Fisheries and Oceans Canada by using a single frequency acoustic system adapted to the AUV. The aim is to evaluate the potential to cost effectively classify seabed habitats as well as to monitor fish and zooplankton abundance and distributions in association with these habitats. The work detailed in this paper concerns the preliminary evaluation of the AUV as a research tool in this context.

I. INTRODUCTION

The MERLIN Lab has been operating the *MUN Explorer* AUV for just over a year. It was originally purchased from International Submarine Engineering Ltd. in Port Coquitlam B.C., Canada, as a survey class underwater vehicle. The *MUN Explorer* is 4.5 meters in length, 0.69 meters in diameter, weighs 650 kg and displaces 660 kg. It has the capacity to handle 200 kg of scientific payload. The vehicle has a potential range of up to 100 km at speeds of up to 2.5 m/s and depths to 3000 metres which makes it an ideal platform for environmental surveys where bathymetric and mapping sonar, physical and chemical sensors, cameras and acoustic devices are carried. Memorial University's previous deployments have included using an Applied Microsystems Conductivity-Temperature-Depth Sensor coupled with a Cyclops Fluorometer, Rhodamine WT, Chlorophyll *a* or Turbidity sensors in order to track simulated and actual effluent waste plumes (Niu et al., 2007).

Operations with the MUN Explorer in September 2007 focused on an acoustic payload as opposed to a chemical sensor payload. The BioSonics DTX Digital Scientific Echosounder (provided by Fisheries and Oceans Canada) was integrated for the purpose of fisheries habitat mapping for an area where a pre-existing multibeam echosounder data set of the bathymetry existed. These data had been gathered from a ship. The motivation for the latest deployments using the acoustic sensor was two fold. The primary goal of the deployments was to evaluate the dynamical stability and accuracy of the AUV when navigating in an area known for strong geostrophic currents (B. deYoung, pers. comm.). The secondary goal was to assess the

Figure 1 MUN Explorer AUV

quality of the collected acoustic data from the AUV compared to that collected from a ship or towfish system.

The identified area of interest was Haystack Bank located in northern Placentia Bay, Newfoundland and Labrador, Canada (47°38.43 N, 54°0.0 W) (Figure 2). The bank is an area measuring approximately 7 km by 4 km with a variation of water depths from 250m to 18m.

The second section of the paper highlights the onboard systems used to facilitate the automated sampling of the echosounder. The third section describes the methodology and evaluation of the dynamical performance and navigational accuracy of the vehicle. The fourth section includes some of the digital acoustical data. A summary and conclusion are contained in the fifth section.

II. SYSTEMS

Typical BioSonics DTX operation includes the Surface Unit, an embedded PC with LINUX OS, which is the signal generator and controls the operation of the transducer(s); a user provided PC running Windows XP to facilitate configuration of the Surface Unit and data storage; a Global Positioning System (GPS) feed; and a digital transducer. To facilitate the integration of the DTX unit with the AUV, it was necessary to modify the existing *MUN Explorer* system. Solutions for the lack of GPS availability underwater and the inability to remotely operate an onboard PC in real time needed to be identified, designed and implemented.

The National Research Council, Institute of Ocean Technology (NRC-IOT), provided an Ixsea Photonic Inertial Navigation Systems (INS) or PHINS unit. The unit has the ability to process output data in a GPS protocol using a NMEA 0183 format as required by the BioSonics DTX. The PHINS also provided enhanced navigation and positional accuracy for the *MUN Explorer* compared with the onboard Watson Attitude and Heading Reference System (AHRS-E304). This is an added benefit of using the PHINS unit which is a preferred INS for the Explorer. Both units remained on board for the duration of the tests.

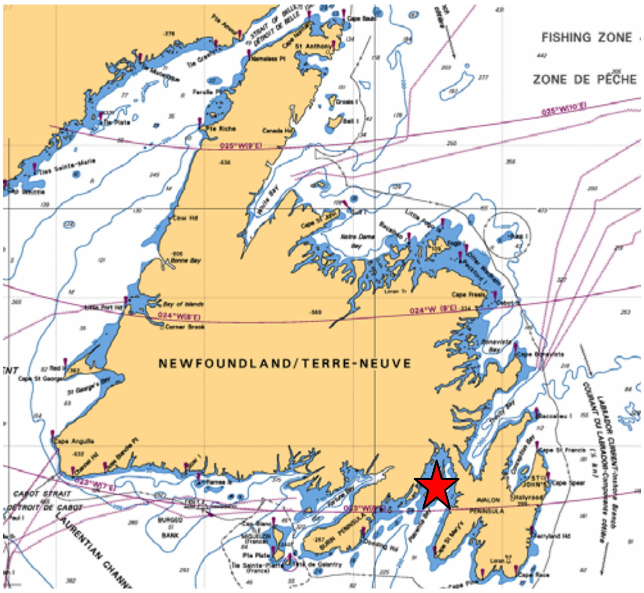

Figure 2 Map of the island of Newfoundland and the study area (marked by the star)

In order to facilitate the remote initialization, operation, and shutdown of the BioSonics Surface Unit, an embedded Compact Peripheral Component Interconnect (CPCI) computer system was integrated to run parallel with the existing vehicle control computer onboard the AUV. The CPCI system employed a Windows XP OS and used software based on IFREMER's (Institut français de recherche pour l'exploitation de la mer) Contrôle de Charge Utile or CCU software. The function of this software is to remotely and automatically control onboard sensor/payload computers and to manage data collection and storage.

III. AUV DYNAMICS

The ISE Explorer class vehicles are capable of subsurface navigation with respect to the seafloor in either a depth or in an altitude mode. In depth mode, the vehicle will maintain a user specified depth (distance below the surface) for a given transect or leg of its mission. When in altitude mode, the vehicle will navigate at a constant user specified range above from the sea floor.

The dynamical behavior of the MUN Explorer was assessed by configuring a mission composed of a series of North to South, South to North, East to West and West to East transects. These entailed vehicle operation parallel and orthogonal to the geostropic currents and over varied sea floor topography. Figure 3 shows multibeam echosounder bathymetry data for the Haystack Bank area. The principal goal was to evaluate vehicle stability when the vehicle was prompted to maintain a consistent distance from the sea bottom at a constant speed. The transects were arranged such that the vehicle would swim with, against and orthogonal to the currents. A hardware constraint for these missions was a maximum depth set point of 75 to 80 meters due to the BioSonics DTX transducer depth limitations. As well, for some transects a minimum depth set point of 5 meters was instituted in order to keep the vehicle fully immersed and less subjected to surface and wind effects.

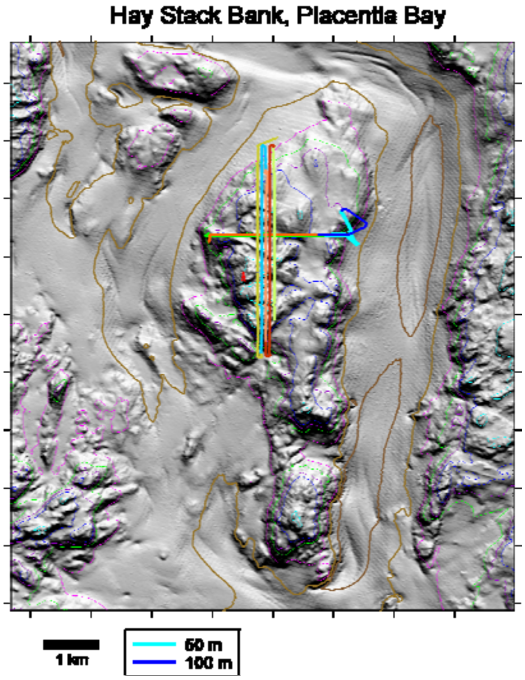

Figure 3 Multibeam data of Haystack Bank (Courtesy of Dr. J. Anderson, DFO)

Figure 4 demonstrates both methods of depth navigation to ensure the vehicle remained at 5 m from the surface while maintaining the specified altitude of the overall mission. The reason for the ceiling requirement was due to the desire to completely eliminate surface effects from the whole dive while traversing over a shallow area (less than 20 m depth).

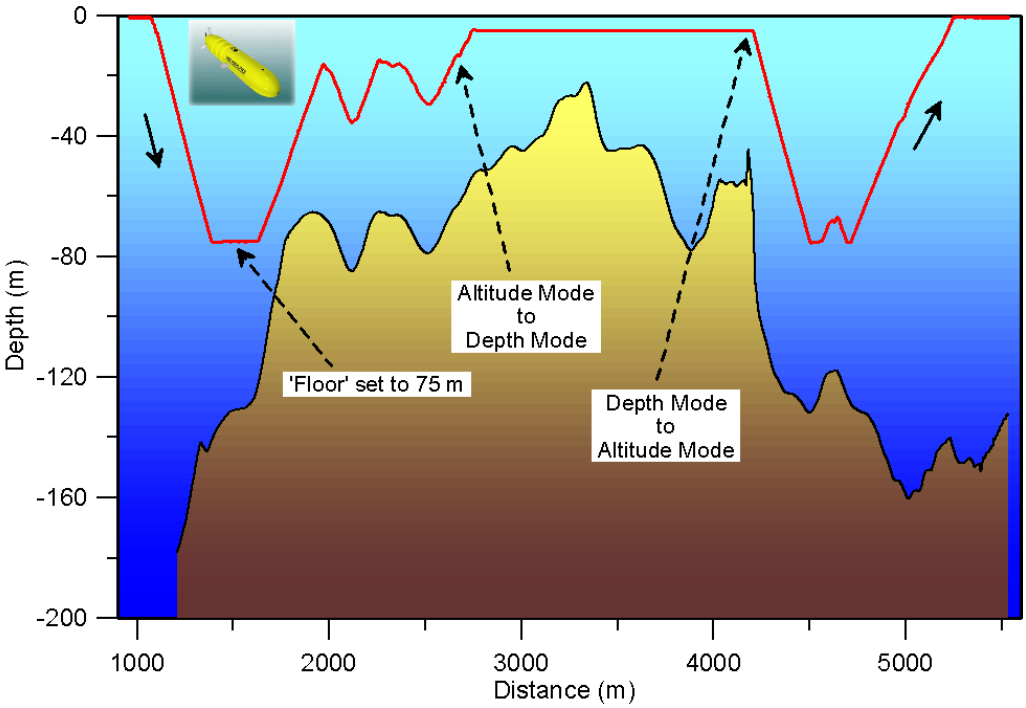

Figure 4 Haystack Bank transect using altitude and depth modes (North-South Line)

The Explorer also has different modes of traversing between depths, i.e. different modes for diving or ascending. In heave mode the vehicle will travel vertically through the water column while maintaining a zero pitch. In pitch mode the vehicle will traverse the water column using a non-zero pitch. This contrast of modes has an important influence upon the angle of incidence for bottom looking acoustic transducers. Figure 5 shows a comparison conducted in each mode, using altitude mode throughout the path with the exception of a small portion over the shallow region of the bank where the vehicle maintained a 5 m depth. The Heave Mode represents the West–East transect that the vehicle flew in a 50 m altitude mode. The Pitch Mode represents the East-West transect conducted along the same track as the previous track, in pitch mode.

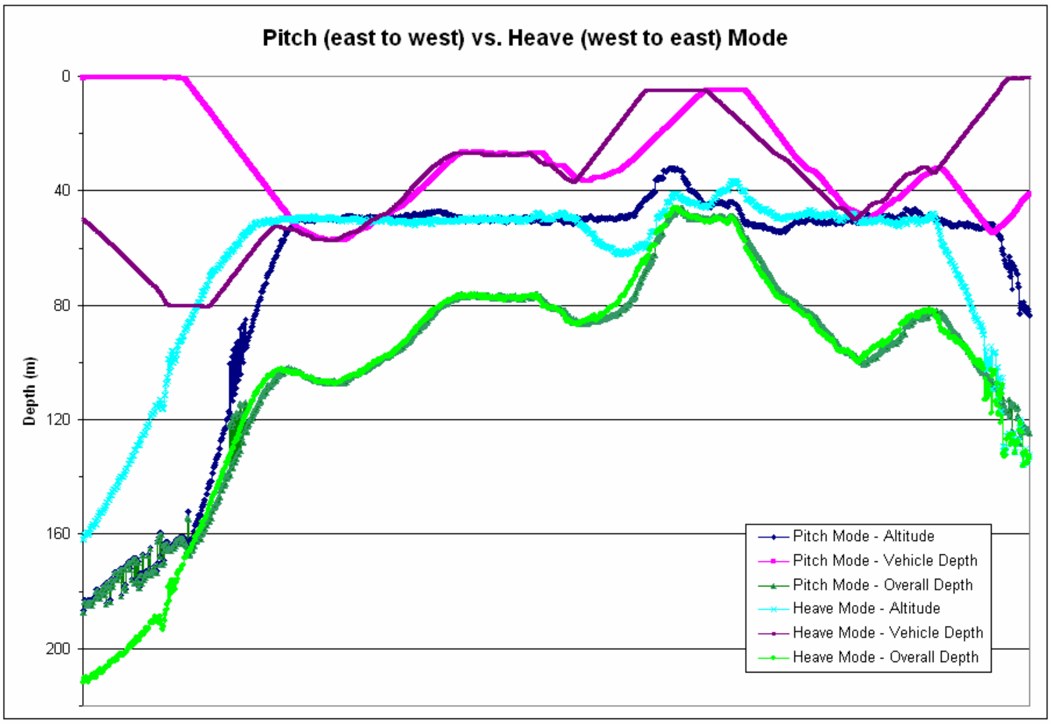

Figure 5 AUV path in pitch and heave modes

From this graphical representation, several conclusions can be made. The overall depth for both transects coincides very well. The altitude perceived by the vehicle (through an RD Instruments Workhorse Doppler Velocity Log) was consistent for regions of the bank that maintained a relatively small gradient (represented by the blue lines for each mode). Deviations from each other occurred at the edges of the bank, or the steeper sections of the transect. It can be noted that the pitch mode dive was able to maintain a higher gradient than the heave mode dive at the west side of the bank. This is also evident in the vehicle depth as shown by the pink/purple lines). The only exception is close to the pinnacle of the bank where the heave mode altitude varies from the pitch mode altitude. This could be an artifact of the directionality of the vehicle, i.e., the AUV traveled from the West to East in the heave mode transect and therefore encountered this feature from a different perspective than the East to West transect.

IV. ECHOSOUNDER

The BioSonics Scientific Digital Echosounder hardware configuration employed for these missions utilized a single split beam transducer with a 120 kHz operating frequency. Frequencies between 10-300 kHz are typically used for the purposes of bottom classification with the ancillary ability to detect fish. The results of these types of studies correspond to the shape and geological nature of the seabed and to the marine organisms present which can include finfish, invertebrates and benthic species (ICES, 2007).

Another goal of the Haystack Bank tests was to verify the effectiveness of the AUV as a platform for fisheries acoustic testing. It is known that AUVs can be inherently quieter than a ship (Fernandes et al., 2000). Further, by taking advantage of the proven vehicle dynamics, one can maintain a steady, constant altitude from the seafloor thereby obtaining a consistent resolution of the data. Finally, any noise from the surface effects of the platform can be eliminated by maintaining a minimum depth during the mission.

The following is a presentation of preliminary results achieved in the Haystack Bank region. Figure 6a shows a small section of the echosounder data captured when the AUV was maintaining a constant altitude of 25 m. At the small hill, the vehicle was forced to surface to maintain its altitude. The surfacing coincides with some noise in the data set. As the vehicle descends, the surface noise is eliminated. In contrast, Figure 6b shows the same track, but with the restriction that the vehicle did not surface during any point during the mission. The vehicle followed the seabed more effectively and the surface noise is not present.

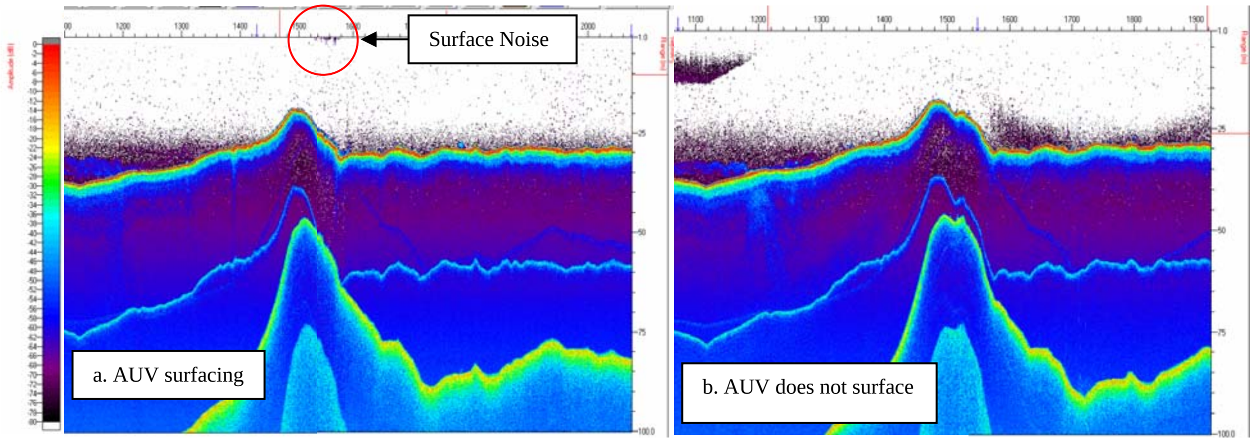

Figure 6 Biosonics DTX data over the same hill, with and without surface effects

V. CONCLUSIONS

The *MUN Explorer* was able to perform the vehicle dynamic tasks while collecting quality fisheries echosounder data efficiently and effectively. The transects performed in the various modes showed the dynamical capability of the AUV given the various mission objectives over complex terrain. Further, the missions proved that the AUV could be used as an alternative platform to a ship for acoustic data collection. Surface noise normally found in data from ship-based missions can be eliminated. A more in depth analysis of the results will be conducted to determine the extent of potential benefits that the AUV can bring to a fisheries survey. However, this initial study has shown that the MUN Explorer is an effective tool in these surveys.

VI. ACKNOWLEDGEMENTS

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