Multibeam Echosounders Capability to Detect Fluid-Mud layers in the Water column

Aluizio Maciel de Oliveira Junior (DHN and UFF) and Ana Angélica Ligiéro Albertoni (DHN)

Abstract

During extreme rain events occurred in Itajaí, SC, Brazil in November 2008, the high water flow in the Itajaí-Açú River caused intense sediment transportation, which destroyed harbor facilities. Several objects, as ship containers, were carried through the channel, forcing maritime authorities to close the harbor in order to guarantee the navigation security.

An expeditionary bathymetric survey has been requested, with the main purpose to quickly map hazards and depth variations within the main navigation channel. The Brazilian Navy Directorate of Hydrography and Navigation (DHN) provided a small team, which has been moved from Laguna-SC to Itajaí-SC, to perform a bathymetric survey using an EM3000 multibeam echosounder. Also, a small boat, termed LB Betelgeuse, had to be moved from Florianópolis-SC to Itajaí-SC. In 2 days, a total of 19 Km distance of channel has been surveyed, from its entrance at seashore until inside the Itajaí-Açú River. A full-coverage seafloor map was built enabling the harbor authorities to safely proceed with further operations in the area.

During this survey, some intriguing echo-character features were detected close to the channel entrance, which has been investigated by divers, proving to be correlated with the presence of fluid-mud sediments. This echosounder has no water column imagery available, so original depth telegram was used. Water column low-density features were unexpected to be detected by the survey team, as they should be filtered out by the bottom tracking algorithms used to calculate the depths. But, this echosounder model demonstrated to be very useful to reliably detect the fluid-mud layers in the water column.

This work presents the fluid-mud echo-character features detected by a multibeam echosounder, so it can be better recognized in the future surveys.

Introduction

The South of Brazil, specially the Santa Catarina State, suffered several problems in November 2008, due to the extreme rain events. Several cities were damaged with flooding and infrastructure problems arose everywhere.

Itajaí harbor, which is the 4th main harbor in the Brazilian harbor´s ranking and exported US$ 5,75 Billion in 2007 (Neto et al. 2009), faced severe destructions, caused by sediment transportation in Itajaí-Açú River. Several objects, as ship containers, were carried through the channel, forcing maritime authorities to close the harbor in order to guarantee the navigation security. This problem caused financial prejudice to local economy. As soon as harbor should be opened, better should be to allow the reduction in financial effects.

The local maritime authority requested DHN support to execute an expeditionary bathymetric survey in the harbor area, focusing on the search of possible navigation hazards and to map locations where depths varied within the main navigation channel. DHN provided a small team to perform a bathymetric survey using an EM3000 multibeam echosounder (Kongsberg, 2005). The local maritime authority allocated a small boat, termed LB Betelgeuse. The team mounted and aligned a portable multibeam structure during one morning period. After 2 days of survey, a total of 19 Km distance of channel was covered, from its entrance at seashore close to buoy number 1 until inside the Itajaí-Açú River. A full-coverage seafloor map was built enabling the harbor authorities to safely proceed with further operations in the area.

During this survey, some intriguing echo-character features were detected close to the channel entrance, which has been investigated by divers, proving to be correlated with the presence of fluid-mud sediments. As the multibeam echosounder used herein is not related in the newest generation sonars list, the water column imaging capability is not available. Using the original depth datagram available in this echosounder, water column low-density not-consolidated sediments were unexpected to be detected by the survey team, as they should be filtered out by the bottom tracking algorithms used to calculate the depths. Methods like gating or neighbor-proximity rules are used to discourage outliers or spurious echoes (J.E. Hughes Clarke, 2006). But, this echosounder model, using only the original depth datagram, demonstrated to be very useful to reliably detect the fluid-mud layers in the water column.

This work presents the fluid-mud echo-character features detected by the depth telegrams of a multibeam echosounder, so it can be better recognized in the future surveys, being very useful in several applications as in dredging works (Craenenbroeck, 1998).

Multibeam expeditionary installation

This survey required an expeditionary survey in order to quickly provide information about the hazards and depth map in the harbor area. For that, the solution using a portable multibeam installation mounted in a pole has been very appropriate.

The pole structure used is very stable and easy to mount. DHN developed and sequentially improved this pole structure after several sea trials, where data quality has been evaluated. Experience demonstrated that light poles are more prone to the water turbulence effects, generating noisy data. On the other hand, more robust pole structures would benefit data quality. As showed in Figure 1, all the multibeam sensors are mounted together in the same pole, allowing easier alignment procedures in the harbor location. Then, pole is transported later to the boat. All these steps: pole mounting, sensor alignments and onboard installation took approximately 2 hours. The main pole used in this survey had approximately 5 meters high, in order to clear the transducer from the boat hull and also the gyro and GPS antennas from the boat superstructure. So, transducers can suffer less water turbulence and gyro and GPS antennas suffer less satellite obstructions. The frame holding the pole is also very important, helping to minimize its vibration. When performing surveys in smaller boats, this pole can be mounted using fewer sections, allowing its size reduction. Each pole section has approximately 1 meter and can be screwed inside the others.

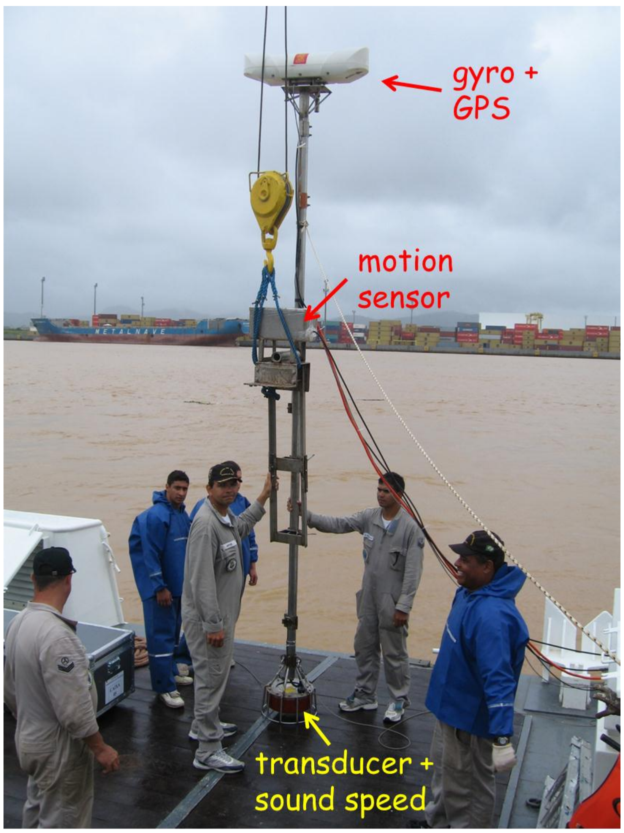

***Fig. 1 –** EM3000 multibeam sensors – pole mounted, ready to be installed in the survey boat (LB Betelgeuse).*

After installing the pole, a patch test has been performed in order to check sensor alignments. For that, the standard procedure has been executed, where several survey lines were compared in order to define the roll, pitch, heave and time delay offsets. This patch test procedure took around 2 hours to be accomplished.

With all alignment steps performed, multibeam echosounder was ready to execute the bathymetric survey. In Figure 2, the survey boat, with the multibeam pole mounted in the port side, is showed close to the harbor pier, which has been destroyed by the water flow strength. The sunken pier structure debris should be accurately detected in the bathymetric survey data.

***Fig. 2 –** Bathymetric Survey close to the sunken pier in Itajaí harbor.*

Bathymetric Survey in Itajaí Harbor

The Bathymetric survey was carried out on 29 and 30 November 2008. Survey covered approximately 19Km, starting in the harbor entrance, close to buoy number 1, going until inside the Itajaí-Açú River, as presented in Figure 3.

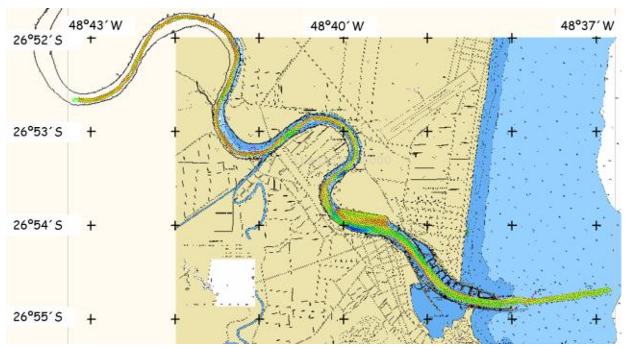

***Fig. 3 –** Itajaí Channel has been surveyed in 2 days with full seafloor coverage.*

The survey data mostly presented a usual characteristic, which team has been used to identify in previous operations. But, in a specific location in the entrance of the channel between buoys 2 and 6, some very strange data started to be logged. First, survey team believed that something (eg. plastic) could be attached to the pole close to transducer location. After stopping the boat and checking, nothing could be found obstructing it. When leaving this area, sounding data became regular again, which induced our understanding that echosounder started to work properly. When coming back to that previous survey region, the same intriguing echo character features showed up again. So, it was evident that this echo-character was real data and should be correlated to that survey area. Apparently, there was something with fluid characteristics, because soundings were scattered through it in the water column. It could be fluid-mud, but also some tree´s trunks sunken in the main channel. The fact is that these cloudy-format soundings were affecting the nautical chart bathymetry and reducing the allowed depths for big ships to access the harbor. As showed in Figure 4, the main channel had depths around 10 m, but this detected objects (signaled in red boxes) were diminishing depths to around 6 m.

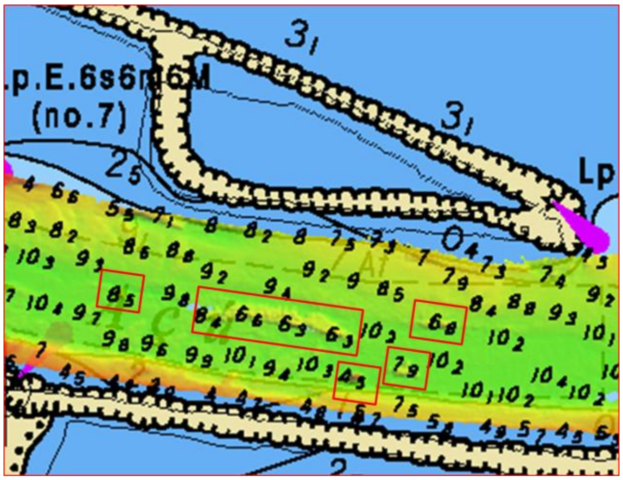

Fig. 4 – *Objects with intriguing echo-character (signalled inside the red boxes) have been detected in the Itajaí Channel entrance, causing reduction in depths allowed for ships from ~10m to ~6m.*

The survey team was not confident to discard these features, cleaning them during data processing, as they had a new intriguing characteristic never observed before in previous operations with this echosounder. Therefore, further investigation, using other methods, should be necessary in order to identify them. For that, a diver team has been used to investigate the area. Dense fluid-mud concentrations were observed in the water column by divers within this area, being correlated in the same location where cloudy-format soundings have been detected. Finally, data could be cleaned out in multibeam data processing, allowing a more realistic representation of the channel seafloor depths.

Fluid-mud echo-character in multibeam data

The EM3000 multibeam echosounder used in this survey has not the water column capability, as available in the newest echosounders versions like EM3002, EM710 or EM2040. The EM3000 logs the depth datagram, which stores the valid detected depths, calculated with phase or amplitude methods depending on beam insonification geometry. Detection methods also optimize target detection using the bottom tracking algorithms, applying gating or neighbor-proximity rules to discourage outliers or spurious echoes. Usually it produces a very robust solution for bottom detection, providing accurate depth information.

As showed in Figure 5, solid objects can be detected precisely, and its shape is well defined through data analysis. This depth solution is benefited from the bottom tracking algorithms described before. In Figure 5, ship´s top view is presented in a map (image A), where its shallower stern superstructure is represented in yellow color. Ship´s side view (image B) highlights that sounding could not be detected inside ship´s hull structure. This is the usual pattern identified by DHN when using this echosounder in harbor surveys.

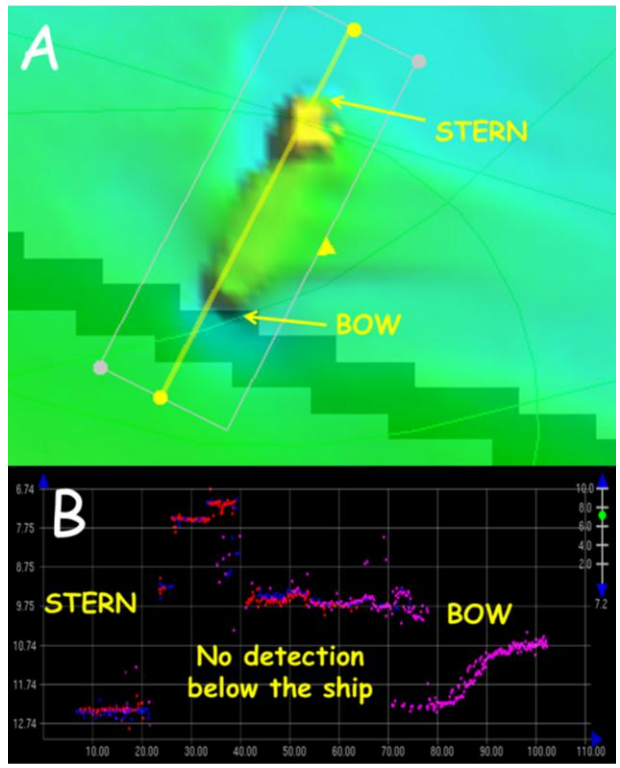

Fig. 5 – *Ship detected with the EM3000 multibeam. Top image A: ship´s top view, with shallower stern in yellow color. Bottom image B: ship´s side view presents no sounding detection inside ship´s structure.*

In this specific survey in Itajaí harbor, the following strange echo character was detected, like presented in Figure 6. As commented before, it indicated the presence of a non-consolidated like fluid density object, but survey team cannot confirm what object it should be. The harbor entrance is showed (image A), with nautical chart represented together with colored multibeam depth surface (Caris, 2007). Fluid-mud echo-character can be identified using a side view or profile view (image B). Herein, the cloudy-format soundings is highlighted, helping surveyors to identify this pattern later in their future works.

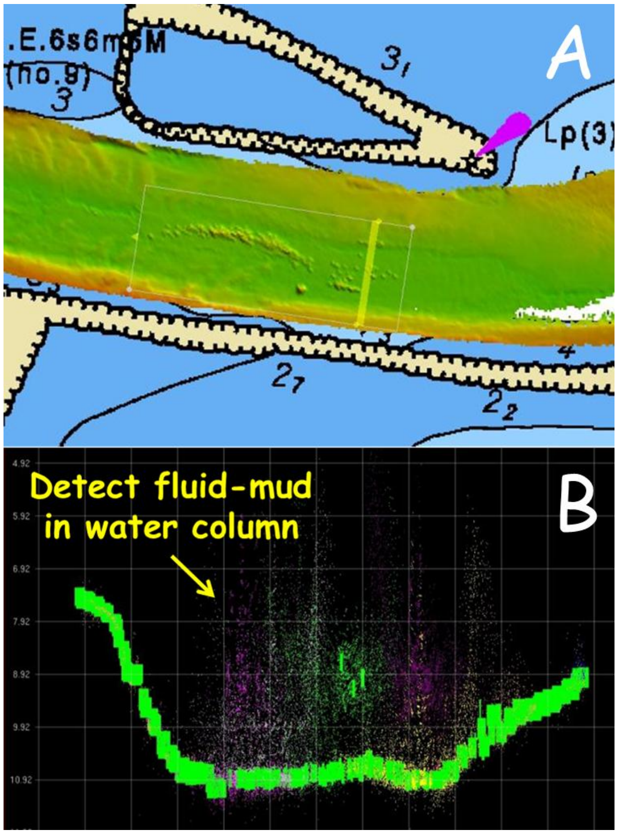

Fig. 6 – *Fluid-Mud echo character pattern detected with Em3000 multibeam in Itajaí Channel. Top image A: channel map. Bottom image B: Fluid-mud pattern.*

As described, this echo-character pattern has been correlated with fluid-mud suspended sediments with the support of a diver team, which has been used to investigate it.

Conclusions

After extreme rain occurred in Itajaí-SC harbor, an expeditionary multibeam survey has been requested to investigate hazards and depth modifications within main navigation channel.

Experience obtained in this survey allowed the identification of fluid-mud typical echo character, when detected with an EM3000 multibeam system. This paper presents this data in order to help other surveyors to identify these features while performing their surveys in fluid-mud areas.

Acknowledgments

The Brazilian Navy Directorate of Hydrography and Navigation (DHN) provided survey equipment.

References

Caris, 2007. HIPS and SIPS Users Guide, Fredericton, NB, Canada.

Craenenbroeck, K.V., J. Duthoo, M. Vandecasteele, J.A. Eygenraam and J.V. Oostveen. 1998. Application of modern techniques in today´s dredging practice. *Terra et Aqua, SEP 1998*.

Hughes Clarke, J.E. 2006. Applications of multibeam water column imaging for hydrographic survey. *The Hydrographic Journal, APR 2006*.

Hughes Clarke, J.E. M. Lamplugh and K. Czotter. 2006. Multibeam water column imaging: improved wreck least-depth determination. *Canadian Hydrographic Conference, MAY 2006*.

Kongsberg Maritime, 2005. EM3000 Multibeam Sonar Operators Manual, Horten, Norway.

Kongsberg Maritime, 2009. EM3002 Multibeam Sonar Operators Manual, Horten, Norway.

Neto, C.A.S.C; B. Pêgo Filho; A.E.Romminger and I.M.Ferreira. 2009. Portos Brasileiros 2009: Ranking, área de influência, porte e valor agregado médio dos produtos movimentados. pp. 72, *Instituto de Pesquisa Econômica Aplicada - IPEA*, June, 2009.