ADVANCES IN SHALLOW WATER MEASUREMENTS WITH OPTECH SHOALS BATHYMETER

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ABSTRACT

Based on many years of operations, Optech Scanning Hydrographic Operational Airborne Lidar Survey (SHOALS) bathymeter has proven to be an accurate, cost-effective, rapid, safe and flexible method for providing depth solution ranging from approximately 1.5 meters to 50 meters in clear water. However, our traditional method of depth measurement has limitations in very shallow water areas where the lidar signals from water surface and water bottom merge. Such limitations inhibit seamless lidar sounding at the land–water boundary, thus restricting much broader application of laser bathymeters in inland environments as well as very shallow coastlines.

In the past, various approaches have been attempted towards recovering lidar points within the very shallow water region but with limited success. Recently, very promising advances in shallow water algorithms have been made at Optech Incorporated, which demonstrate airborne lidar bathymeter depth-sounding capability in extremely shallow water as well as seamless lidar depth solution across the land–water boundary. The following graphs give an overview of some of our recent achievements in surveying very shallow water by the Optech SHOALS bathymeter.

1. INTRODUCTION

Airborne laser bathymetric systems exploit time of flight photon echoes to determine the depths of water bodies. The Optech SHOALS system uses a combination of multiple wavelengths and scanning mirrors in order to accurately sound depths up to 30 m, with horizontal resolution selectable between 2 and 5 m spot centers.

Fig. 1 illustrates key points in laser bathymeter operation. An aircraft is shown flying over a body of water.

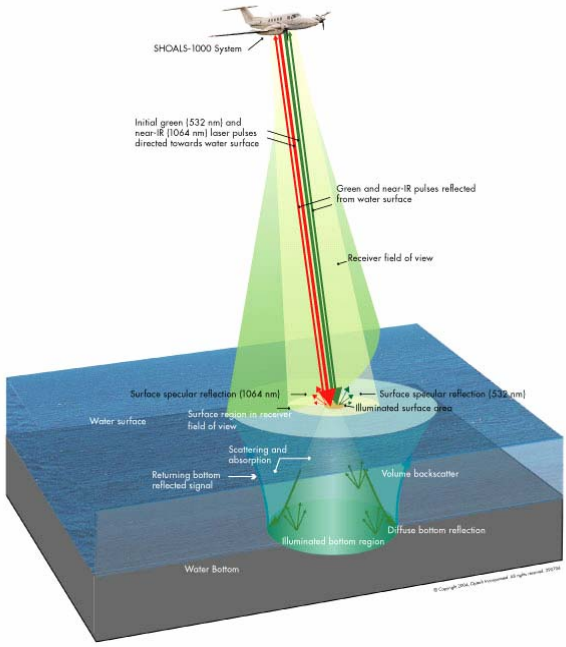

Fig. 1: SHOALS principle of operation

Two arrows, red and green, are shown propagating from the aircraft and represent two wavelengths, at 1064 and 532 nm respectively. The near infrared (NIR) wavelength at 1064 nm is used to obtain a strong surface signal, triggering the data collection. The green wavelength at 532 nm penetrates and propagates through the water surface and is used for the depth sounding. Due to the scattering properties of water, the spot size within the water column flares out in a trumpet horn shape. The light propagates to the bottom of the water body, at which time it is echoed back to the airborne instrument and by means of its round trip time recorded as a depth sounding. In order to collect swaths of depth data along the flight path, the beam is scanned across the surface of the water as the aircraft is in flight. However, in order to ensure that the beam characteristics, such as beam spot size, are consistent, the entry angle into the water is held constant. For this reason, the bathymeter scanner slews in an arc, maintaining a constant nadir entry angle for the light, rather than a simple back-and-forth pattern.

Water clarity ranges widely, and even in the best of conditions strongly scatters and attenuates light. For this reason, the airborne bathymeter is confronted with a side dynamic range for returned optical echoes. The returned optical signal is amplified with a variable gain logarithmic amplifier which enables the system to accommodate optical signal strengths over an 80 dB range.

Integrated with the SHOALS system is a digital camera. Compact Airborne Spectrographic Imager (CASI) systems are also available for enhanced analytic capability.

The advantages of coastal water airborne bathymetry over SONAR are described in Fig. 2. The swath detected from the aircraft is shown compared to the soundings taken from large surface vessels to the left of the cartoon and smaller surface vessels towards the shore. Given the smaller footprint of the surface vessels and their much slower speed, the advantages of airborne laser bathymetric systems is immediately apparent. It takes hours to provide depth charts for airborne systems as opposed to weeks for surface vessels. Also note that the bathymeter is capable of retrieving information from water so shallow that even small surface vessels have difficulty accessing it. The bathymeter is even capable of retrieving signals from land.

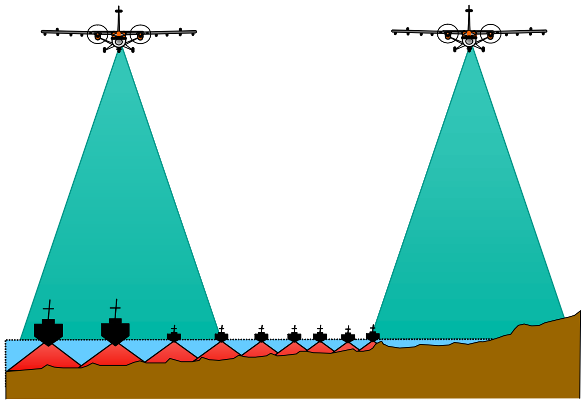

Fig. 2: Advantages of SHOALS over SONAR in coastal water sounding

SHOALS Specifications for two systems are shown in Table 1:

Table 1: SHOALS System Specifications

Parameter	Values	
System Name	1000 T10	3000 T20
Hydro Collection Rate (Hz):	1000	3000
Topo Collection Rate (Hz):	10,000	20,000
Depth Measure (m):	50	50
Depth Penetration:	2-3 x Secchi	2-3 x Secchi
Operating Alt. (Hydro) (m):	200 – 400	300 – 400
Operating Alt. (Topo) (m):	300 – 700	300 – 1200
Aircraft Speed (Knts):	125–180	125–260
Laser Spot Spacing (m):	2 x 2, 3 x 3, 4 x 4, 5 x 5	2 x 2, 3 x 3, 4 x 4, 5 x 5
Swath Width (decimal fraction of altitude)	≤ 0.6	≤ 0.75
5 x 5 m Coverage ($km^{2/}$ hr)	77	144
Vertical Accuracy:	IHO order 1 (± 25cm)	IHO order 1 (± 25cm)
Airborne Weight (kg):	205	210
Power Requirements (A@28VDC):	66	75

Shallow water bathymeter application is discussed in the following section.

2. DISCUSSION

Shallow water bathymetry presents the problem of being able to distinguish surface and bottom signals as well as signal returns from in between, if the shallow water is turbid as is frequently the case. However, Optech has made significant advancements in their shallow water algorithm research over the past several months. Field test results over various shallow water test sites located in various continental waters has thus far yielded results from depths of 1 m or less. The following are preliminary results from two of these test sites.

Fig. 3 is a digital camera image detailing a small portion of test survey site 1 in a lagoon. The image, taken with the SHOALS down-looking integrated digital camera, shows a mottled effect, darker areas and lighter areas. Such contrasts could have many explanations, but are clearly understood when one looks at Fig. 4.

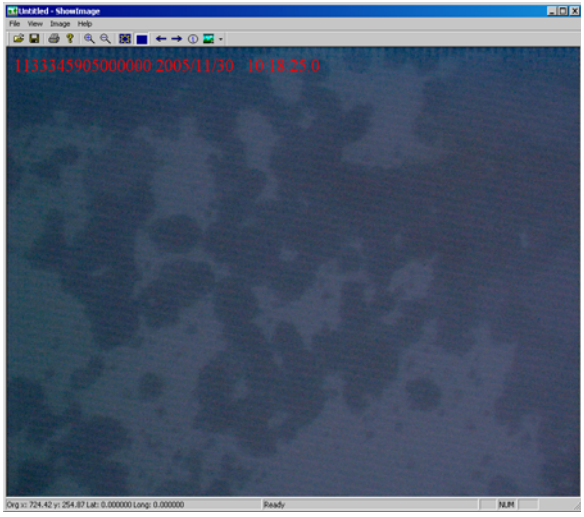

Fig. 3: Digital camera image

Fig. 4 is a detail of SHOALS data in the lagoon, corresponding to the same area as imaged in Fig. 3. Note the arc-like scan pattern, enforced upon the laser path and field of view in order to ensure that the nadir entry angle remains constant. The average depth shown is around 1.5 meters. Yellow to green colors indicate shallower depths. Blue colors indicate deeper depths. There is a sharp contrast between the blue regions and other colors, creating the same mottling effect as seen in Fig. 4. The shallower depths, and the changes in image contrast seen in Fig. 4, are presumed to indicate the presence of vegetation. The height of the vegetation rises 10 to 50 from bottom of the sea floor.

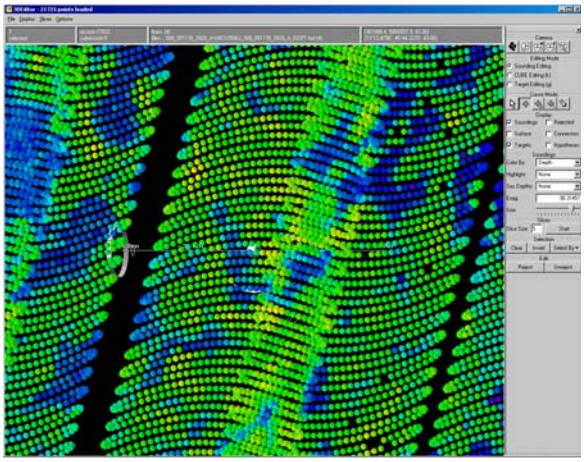

Fig. 4: Detail of SHOALS data

Further detail is available from SHOALS data. Fig. 5 displays data, corresponding to the lidar elevation map shown in Fig.4 and illustrating details of bottom vegetation. The bottom vegetation heights range between 30 and 50 cm in this case.

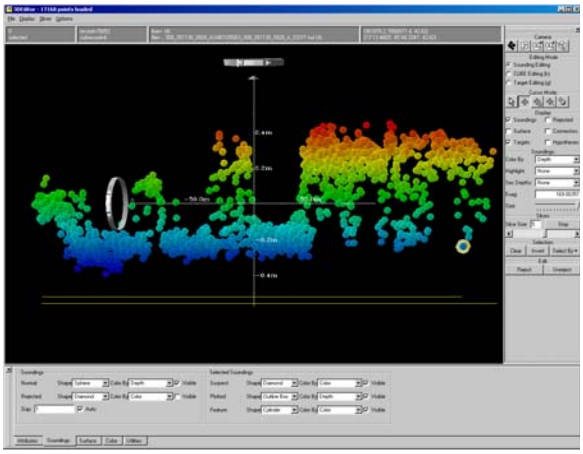

Fig. 5 : Profile of the details shown in Fig. 4; from the scale shown in the image

Fig. 6 is an image detailing a small portion of test survey site 2 in a shallow water riverine and floodplain area. The majority of depths in this area were between 1.2 and 1.8 meters. The water clarity was excellent and the bottom consisted primarily of gravel and cobblestone with some larger rocks. Many areas along the river were impassible due to log jams.

Fig. 6: Image of shallow river waters

Fig. 7 illustrates SHOALS data results that were processed using the traditional depth extraction algorithm. This algorithm is effective primarily in waters deeper than 2 meters, thus most of the riverine data, shown in Fig. 7 in red, was not retrievable. Substantial ground coverage data on the edges of the river were captured as can be seen in Fig 7.

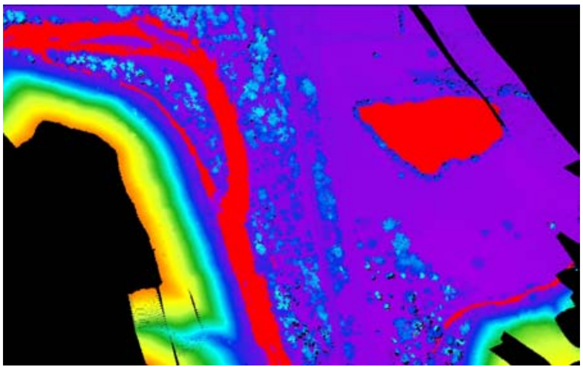

Fig. 7: River area and smaller lake to right were all non-retrievable with traditional depth extraction algorithm – shown in red

The 3D data illustrated in Fig. 8 was passed through the prototype shallow water algorithm where the majority of depths were retrieved.

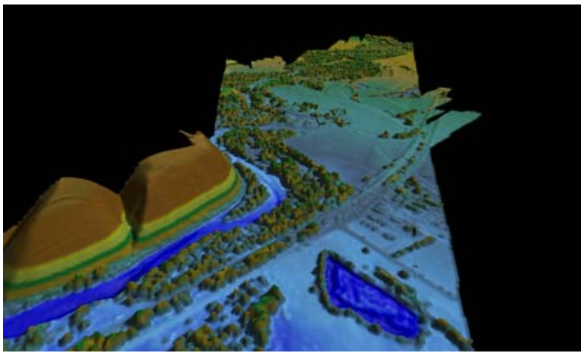

Fig. 8: 3D view of retrieved river data and lake to the right side of the river

Fig. 9 is an image detailing a small portion of test survey site 3 in a shallow water intercoastal canal area. The majority of depths in this area were between 1 and 3 meters. The water clarity ranged from average to excellent.

Fig. 9: Shallow water canals

Fig. 10 is a 3D point display, side view, of the canal. The raised group of points in the center (dark blue) off the tip of land (light blue) is a sand bar. The water covering the sand bar was approximately 1.5 meters deep and the canal area was approximately 3 – 4 meters in depth.

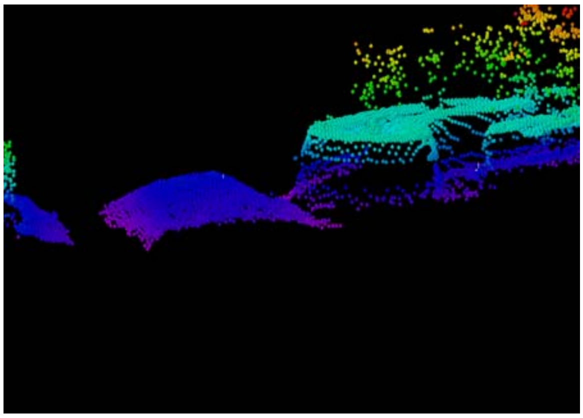

Fig. 10: Side profile of a 3D point display of the canal. Note the sand bar in middle of point display

3. CONCLUSIONS

Advances in shallow water algorithms demonstrate great potential in providing seamless lidar solution by the Optech SHOALS bathymeter. SHOALS has unique capability in measuring shallow bodies of water (< 2 m) with great speed and accuracy. The SHOALS instrument thus has a demonstrated capability to provide accurate dry-land topographical measurements as well as depth measurements on the coastline and further into deeper waters. The dynamic range of the returned optical signal is ably managed through the SHOALS signal processing electronics.

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