United Kingdom
Hydrographic Office

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UKHO Satellite Derived Bathymetry trial and charting considerations

1. Introduction

This paper gives a summary of the UKHO Satellite Derived Bathymetry (SDB) trial and goes on to provide recommendations for representation of SDB data on paper charts and ENCs.

UKHO considers that good quality SDB data, used appropriately, is able to provide valid information that can be used to make navigational products safer. UKHO have been assessing the accuracy of SDB and the most suitable methodology for representing SDB data on charts. The aim is to have the ability to be able to quality control and use SDB data as source data for navigational products. This will allow UKHO to make use of this technology in areas where modern survey data is lacking and more conventional methods would prove too difficult or not cost effective.

2. Background

SDB technology was developed in the late 1970s, but recent advances in satellite imagery technology, such as improved resolution and multi-spectral bands, have increased its potential as a source of hydrographic data. The use of SDB data is increasing throughout the hydrographic industry as a low cost source of data.

In general, SDB data can offer:

1. **Good coverage** (within depth and image limitations); not as good as Multi-beam echo sounder (MBES), some objects may be missed, but better than single-beam echo sounders (SBES) and leadline.
2. **Better object detection than leadline**, but not as good as SBES used with side scan sonar or a MBES.
3. **Good positional accuracy**. Similar to MBES and SBES. Better than historic leadline.
4. **Lesser depth accuracy** than MBES, SBES and leadline.

SDB is based on the expectation that deeper water appears darker than shallower water. This simple analogy is complicated however as a shallow black rock can appear darker than surrounding deeper sandy seabed. Complex mathematical analysis of the imagery attempts to distinguish these differences and remove the many other sources of ‘noise’ in a satellite image and produce a best estimate for the average depth in each pixel.

Unlike “active” depth measurement techniques such as echo sounders or Light Detection and Ranging (Lidar), where controlled signals are transmitted and received, SDB is a “passive” technology and is simply measuring the reflected sunlight intensity. Because of this, SDB results are affected by many more uncontrollable environmental factors.

SDB is limited to shallow clear waters where the seabed can be seen in the imagery. Its results can be adjusted and improved by providing “ground truth” data using more conventional survey techniques (e.g. echo sounder).

Industry claims of accuracies of 10% of depth were not borne out by early experiences of SDB within the UKHO. UKHO decided in 2013 to conduct a controlled trial to fully understand the accuracy and reliability of SDB.

3. UKHO SDB Trial

3.1. Goals

To allow the UKHO to make an informed decision regarding the suitability of SDB as a data source for navigational products and, at the same time, gain an understanding regarding the optimal parameters for SDB data acquisition.

3.2. Method

To acquire the best quality MBES and SDB data within a given area and compare them, using the MBES data as the benchmark.

UKHO conducted a high resolution, high quality, MBES survey along the south coast of Antigua in September 2013. This area was chosen for the trial as it offered clear water with a range of depths and a mix of simple sand and complex coral seabed.

The MBES data typically met the vertical and horizontal uncertainty requirements for S44 "special order", the object detection requirements for S44 "Order 1a" and CATZOC A1.

Satellite imagery was tasked with optimal parameters and acquisition that took place during the MBES survey in order to remove any doubt that the seabed could have changed. Imagery was acquired from the Worldview-2 satellite, one of the most advanced civilian imagery satellites available at the time of the trial, with a pixel resolution of 2m.

The imagery was processed using several different SDB processing methods and ground truth data, both in-house and through commercial companies, in order to compare them and understand the repeatability of this technology.

All data was corrected to chart datum using observed tides.

3.3. Results

Results were looked at in terms of both overall accuracy (compared to MBES dataset) and SDB's ability to define critical soundings. These factors were then used to assess a suitable CATZOC classification for SDB data. All the conclusions are based on the most accurate SDB dataset from the trial (which was provided by ground truthed data from one of the external companies).

A series of profiles were taken showing the MBES data against different versions of the SDB data. These are shown below and indicate that SDB is able to detect the general shape of the seabed.

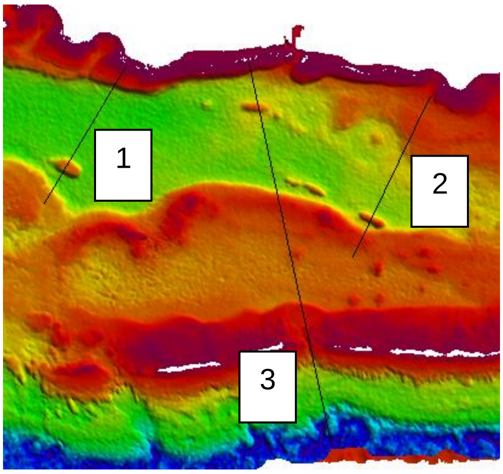

Figure 1 - SDB data showing the location of the profiles

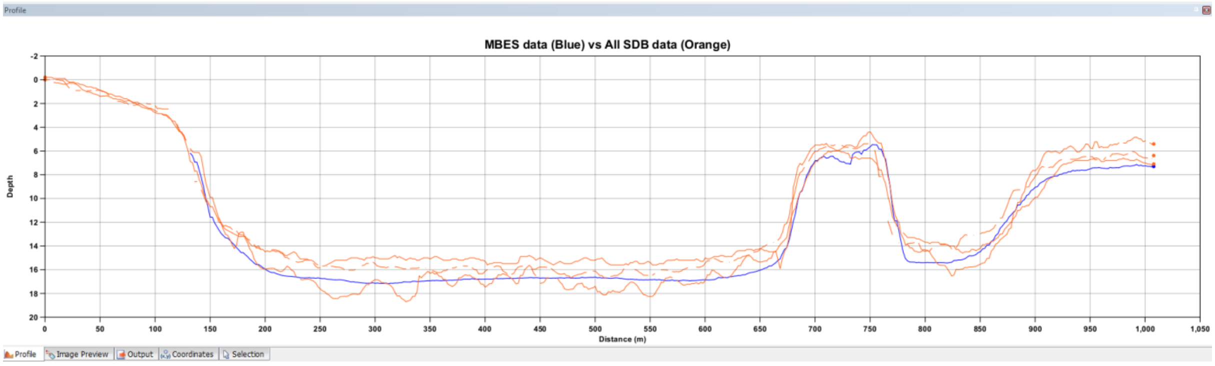

Figure 2 – Profile 1 - MBES data (blue), All SDB data (orange)

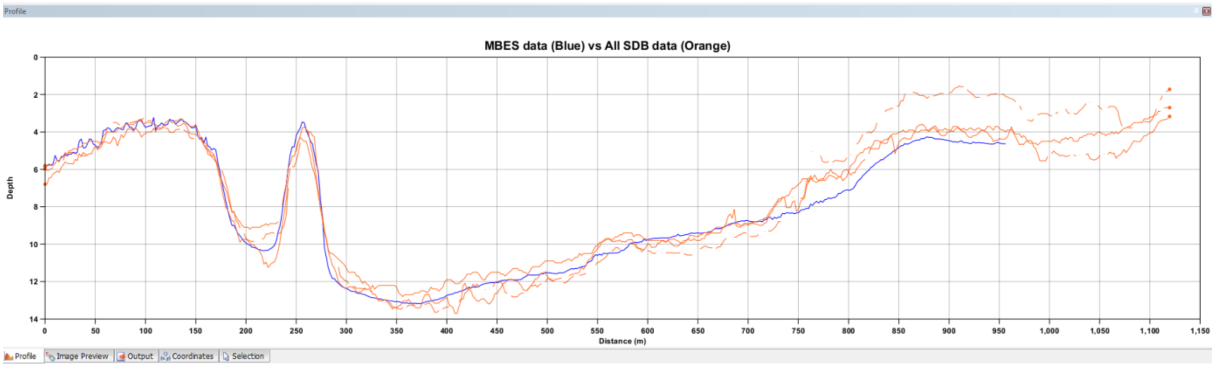

Figure 3 - Profile 2 - MBES data (blue), All SDB data (orange)

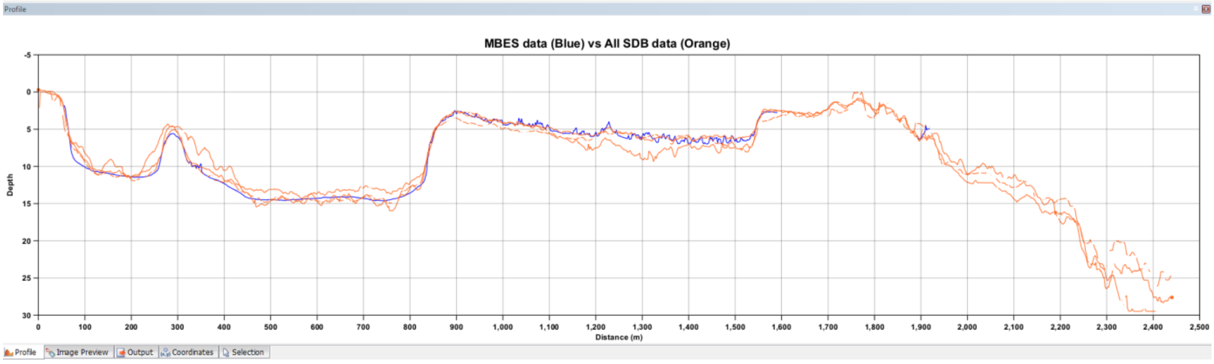

Figure 4 - Profile 3 - MBES data (blue), All SDB data (orange)

The most significant soundings from the MBES and the SDB data were compared and these are shown in the figures below. The area was previously charted using only leadline data. Three critical soundings were identified from the MBES data (as highlighted with the white arrows). These were also detected in the SDB data and depths were within 0.7m of the MBES data. Other soundings shown are within 2m of the MBES data.

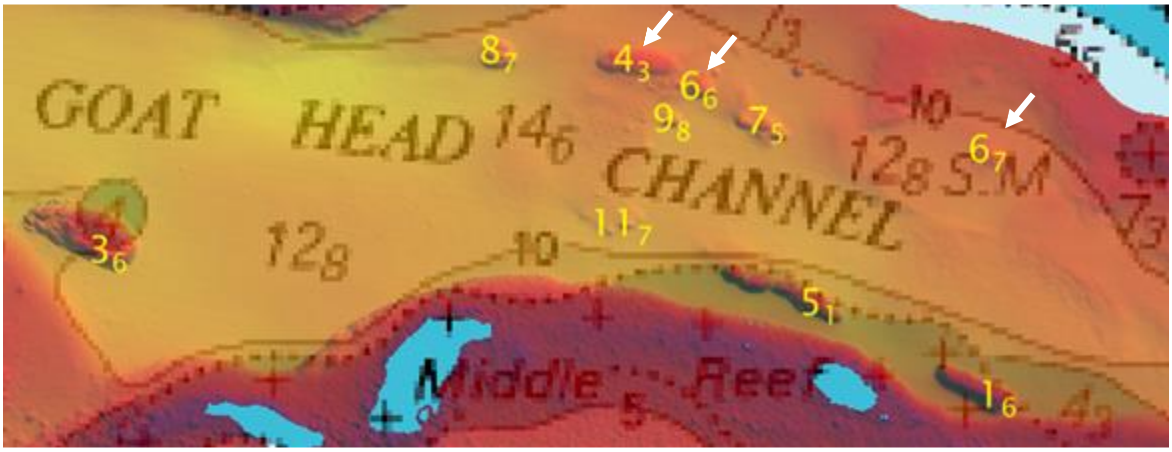

Figure 5 - MBES depths

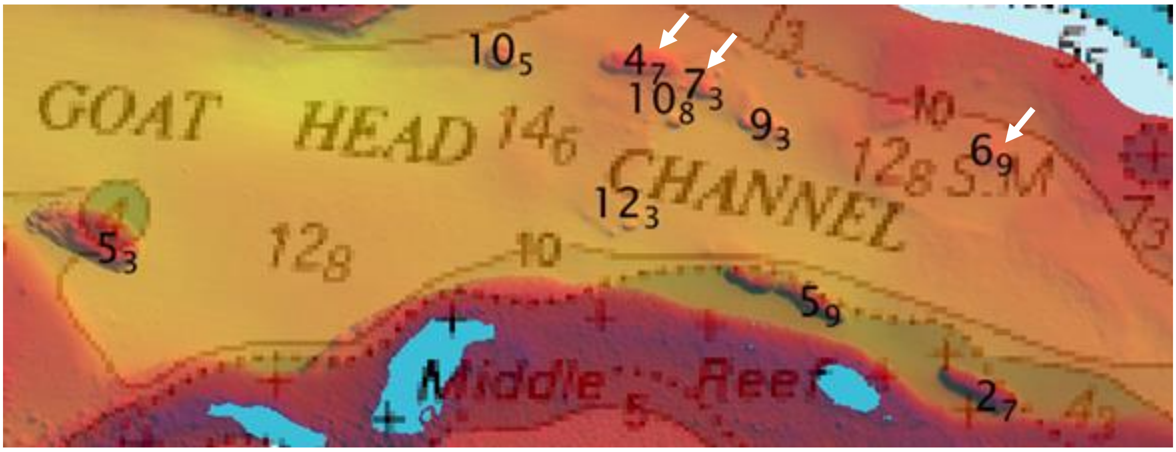

Figure 6 - SDB depths

Difference surfaces were created and coloured to show areas where the SDB data is within 2m and 3m of the MBES data. These are shown in the figures below.

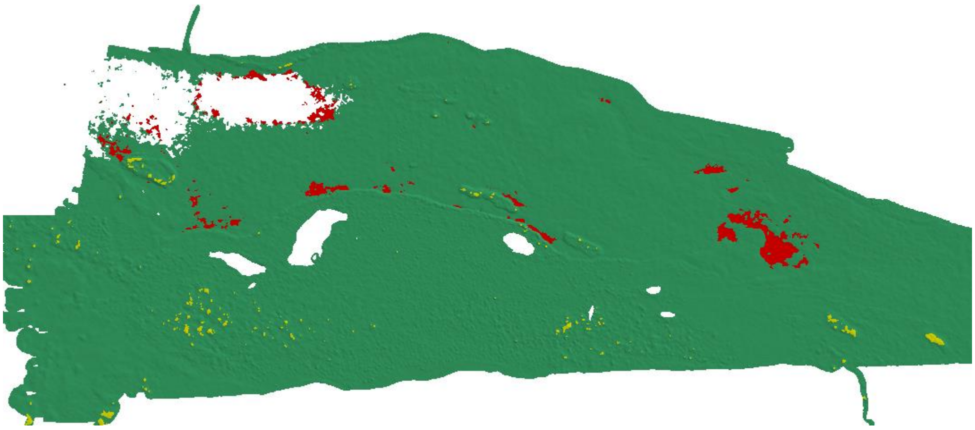

Figure 7 - Green SDB is within ±2m to MBES. Yellow SDB is deeper. Red SDB is shoaler

Figure 8 - Green SDB is within ±3m to MBES. Yellow SDB is deeper. Red SDB is shoaler

The difference surfaces were compared to the depth accuracy requirements for CATZOC C. It was found that for the best data set from the trial (which had ground truth data applied to improve the results) more than 97% of the SDB data was within the CATZOC C depth accuracy requirements from the MBES data. Without ground truth data applied only 79% of the SDB data met CATZOC C requirements. With a horizontal accuracy of ~5m all the SDB data easily meets the horizontal accuracy requirements for CATZOC C (500m).

3.4. Conclusions

Like a conventional hydrographic survey, different processing methods make a clear difference to the SDB data. Validation of both source imagery and processing is required to ensure optimal results are achieved.

Using ground truth data improved the SDB results.

The uncertainty of the SDB data increased with depth. In the case of this trial, only SDB data shallower than 15m was considered reliable. It is expected that this ‘cut-off’ depth would be different for data acquired in different areas and from different imagery. The actual cut-off depth can only be determined reliably using ground truth data.

The SDB trial data does not meet IHO S-44 survey standards. Though more than 97% of the “Commercial Company 1” data could be categorised as CATZOC C, the data that fails CATZOC C requirements is spread throughout the data set and would be difficult to delineate. SDB has detected the majority of features though, which is in the spirit of CATZOC C, and unlike traditional CATZOC C data, such as leadline, does not consist of large areas where no data exists at all. Until further work has been done on quality control parameters and error budgets, ground truthing would be required to prove that CATZOC C had been attained.

The trial SDB data was accurate to approximately ±2-3m when compared to the MBES data, though much of the data was better than this.

Though SDB technology is not able to match echo sounders for accuracy it can give an indication of the shape of the seabed. It is likely that some features will be missed and though the technology can obtain depths as deep as the water clarity will allow, the reliability of these depths greatly decreases as the depth increases.

This trial was conducted in waters that are favourable for the use of SDB and using high resolution imagery. Further work is needed to assess the performance of SDB in less favourable conditions and with lower resolution imagery.

In this case, the ground truthed SDB data was capable of making the chart safer.

4. Representing SDB on charts

UKHO consulted a representative panel of mariners from across the shipping industry for their opinion on the representation of SDB data on charts.

The general opinion was that they would like to know where SDB survey data is used on a chart, but there was a preference not to use any additional symbology over and above the standard depiction of soundings. There was a preference to use the source diagram and chart notes to assess the level of confidence with survey data.

Taking account of the mariner opinions and our own internal analysis and discussion, UKHO has determined that there is no requirement to differentiate soundings derived from satellite bathymetry on the chart face itself. This is due to the observed level of data accuracy (see CATZOC analysis at 3.3 above). Instead, as with data from all traditional origins, we are proposing to bring areas of satellite derived bathymetry to the mariners attention using the source diagram on the chart, stating the method of acquisition used and the date of survey. However, noting that the mariners also requested chart notes and the fact that the shortcomings of this new data source are not widely understood within the industry, UKHO considers that a chart note should be included, for example:

SATELLITE DERIVED DEPTHS

Depths within the area shown on the source diagram are mainly derived from satellite imagery. Their vertical accuracy is typically ± 3m. Uncharted dangers may exist. For further information, see Admiralty publication ‘The Mariner’s Handbook’.

An associated legend ‘*Depths (see Note)*’ and (where the extent of the area may not be sufficiently delineated on the source diagram) an area limit using existing INT1 I25 should also be included.

5. Overall Conclusions

As with all survey techniques, it is possible to acquire both good and bad SDB data. In the UKHO trial it was shown how ground truthing can greatly improve SDB results and also provide evidence of the data meeting an IHO standard. The results of the trial don't imply that all SDB is fit for charting, only where best practices have been followed.

Though confidence in SDB data is lower than echo sounder surveys, SDB data is capable of providing useful information at least as good as leadline survey data. Leadline surveys do not necessarily find all the shoals in an area due to the technique and the same can be said for SDB but for different reasons.

Good SDB data can be of value when navigating but the mariner needs to understand the uncertainty of the data and how it differs from surrounding data in order to use it appropriately.

New symbology is <u>not</u> required to represent SDB data on paper charts and ENC.

6. Recommendations for charting SDB data

a. SDB data should be validated by conventionally obtained data (e.g. by echo sounder), known as ground truthing and if it can be proven thereby to be sufficiently accurate, assigned a maximum of CATZOC C on ENCs and depicted using standard italic black soundings on paper charts.

b. Caution should be given to any SDB data where the provenance of the imagery is not known and ground truthing has not been conducted.

c. SDB data should not be used to disprove existing charted shoal depths, but it may be used to improve the position of shoals derived from surveys based on old positioning methods.

d. Any dangers discovered by SDB should be charted but it should not be implied that further dangers do not exist.

e. Source diagrams should identify where SDB data has been used and reference the date of the imagery acquisition (not the date the bathymetry was computed).

f. Notes should be added to charts explaining the shortcomings of SDB data.

g. Areas containing mainly SDB data may exceptionally be identified on the face of the chart by a limit if: there is no source diagram or it is considered that the Source Diagram cannot depict it accurately enough; where the provenance of the imagery is not known; where the vertical accuracy cannot be assessed because ground truth data has not been obtained.