



## COMPARATIVE STUDY BETWEEN FLAT AND UNIFORM BOTTOM ASSUMPTIONS FOR SNIPPET IMAGERIES IN HYDROGRAPHIC APPLICATIONS

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### ABSTRACT

The length of each snippet data varies with the ensonified area of the beam foot print, which is a function of incidence angle and water depth. Generally, the seabed topology is undulated and it is challenging to determine the exact angle of incident. Therefore the snippet is divided into two operational modes; uniform and flat bottom in order to cope with the complexity of the seabed. However, these assumptions are invalid in real situations most of the time. This study focuses on comparing these two bottom assumption techniques in bottom classification and coverage accuracy using the RESON Seabat 8124 multibeam system at Johor Bahru, Malaysia. Comparative analysis were carried out using hit counts and data gaps interpretation for geometric distortions, intensity profiles and volume comparisons for radiometric distortions in the classified mosaic seabed imagery. Both modes gave a mean difference of 0.54 intensity units on flat seabed areas and 5.97 units on the slope. The data density of the uniform mode is also high. This concludes that one may use either technique for flat areas. But for undulated areas, one has to be careful in selecting the snippet modes, as the real seabed is not completely flat or uniformly sloped.

*Key words: Multibeam Backscatter, Snippet, Seabed Imagery*

### 1.0 INTRODUCTION

Multibeam Echosounder Systems (MBES) use acoustics beamforming and bottom detection techniques to develop a cross-section (swath) data of the seafloor. MBES have the possibility to obtain full bottom coverage and can provide high resolution seabed topography depending on the beam width. MBES use the two way travel time of the returned acoustic signal for the depth measurements. A common by-product of MBES is a measure of the backscattered acoustic intensity from the seafloor. This backscattered energy depends both on the seafloor physical properties themselves and also on the sonar configuration, water column propagation and measurement geometry. Based on the characteristics of acoustic backscatter intensity over the region, seabed can be segmented into discrete classes which produce a map of acoustic diversity (Siwabessy, 2001 and Oliveira, 2007). Maps of acoustic backscatter data can also be used to interpret physical properties of the sea bottom such as impedance, roughness and volume in-homogeneity (Preston *et al.*, 2000). Over the years, multibeam backscatter data has been used extensively as a source for seafloor classification.

Since MBES is designed preliminary for bathymetry, the proper reduction of the backscatter data is of secondary importance and is often neglected by the system designers. In order to make use of this data, one has to apply various types of corrections. Beam pattern residuals, measurement of seabed slope, spherical focusing, determination of the grazing angle due to refraction, signal attenuation and noise, removal of the angular dependency are the most common among them (Calder and Mayer 2001; Beaudoin *et al.*, 2002; Pillai and Supriya, 2009). These geometric and radiometric modulations and other related effects on the backscatter intensity must be reduced, such that the backscatter strength become a useful signal for the task of seafloor physical properties characterisation (Gavrilov *et al.*, 2005 and Intelmann *et al.*, 2006).

There are two types of multibeam backscatter data; multibeam side scan and snippet. Multibeam side scan produces two arrays of amplitude time series on port and starboard sides at each swath ping. Snippet provides amplitude time series at each beam footprint corresponding to each beam of the MBES ping (RESON 2010). Then the average intensity value is logged in the system per each beam analogous to the depth values per each beam in the MBES. Therefore, there will be same number of snippet data values as the number of the beam number of the corresponding MBES.

The length of each snippet will vary as a function of the individual beam angle and water depth. In the final backscatter signal computation, the angle of incident of each beam with the seabed and the total ensonified area must be determined (Burdick, 1984 and Hammerstad, 2000). Usually the true seabed is an undulated terrain, thus the seafloor classification with the multibeam backscatter becomes challenging when it comes to determination of the true backscattered signal. Incorrect seabed slope calculation will result incorrect incident angle calculation and incorrect beam ensonified area calculation. This will lead to both radiometric and geometric distortions of the final backscatter image. Therefore accurate determination of the seabed topography is critical for snippet data. Hence, RESON has divided the snippet data collection into two operational modes; uniform and flat bottom assumption (RESON, 2010) to mitigate this problem. In the uniform bottom technique, it assumes that the seabed uniformly inclined ( $1/16 \times \text{range}$ ), while in the flat bottom technique, it is assumed that the seabed is truly flat.

However, the true seabed is neither flat nor uniformly sloped as in either snippet assumption modes. Therefore, a problem arises when the true seabed is different from assumed slope. This will lead to erroneous modelling of the backscatter intensity than the true one. This paper focused on performing a comparative study between the flat bottom and uniform seabed assumption technique in snippet seafloor classification and bottom coverage accuracy.

## 2.0 METHODOLOGY

In this study, the snippet data was collected with flat-bottom and uniform-bottom modes over the same area in order to carry out the comparative analysis. However, only one snippet mode data can be collected at one time with the MBES processor. Therefore the same survey line was repeatedly surveyed having the different modes at the Pantai Lido, Johor Bahru, Malaysia using the RESON Seabat 8124 multibeam system. Respective snippet modes were selected in the BITE screen in the sonar processor. Same survey line was repeatedly surveyed having the same snippet mode both up and down direction for the redundancy of the data. QINSy 8.0v software was used in the data collection and processing. Prior to the snippet data processing, the multibeam system calibration was carried out for the mounting offsets. Then the tidal values were applied to the data set.

## **2.1 Snippet Data Processing**

Before the final snippet mosaic generation, the data must be corrected for vessel altitude, refraction and slant-range corrections. The beam pattern, Time Varying Gain (TVG) and gain corrections were not considered in this case as it surveyed the same area. This does not effect the final results as the effects get cancelled out in the final comparative analysis. Here, a complete seabed interpretation was not considered and the relative effects of each snippet seabed assumption mode are considered.

The snippet data was obtained by a side-mounted MBES and the corresponding altitude variations are directly related to vessel motion. The real time vessel altitude data is measured with the onboard motion sensor and applied real time to the snippet data. Similarly the sound velocity profile is also measured and applied during the survey. The slant range correction for the high intensity nadir beams are applied in QINSy side scan viewer.

## **2.2 Snippet Mosaic and Bottom Classification**

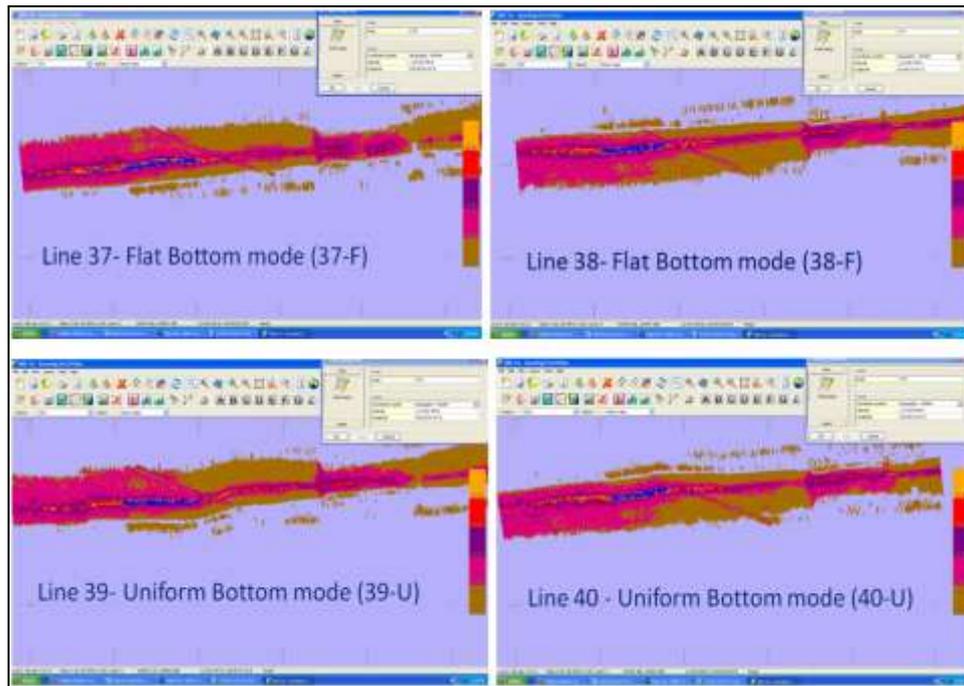
The snippet mosaic was generated using the Sounding Grid Utility (SUG) tool in QINSy software. Each data line was assigned to separate layers in the same sounding grid for comparison. Lines 37-F and 38-F were flat-bottom mode and the lines 39-U and 40-U were uniform-bottom mode respectively. Additionally, another sounding grid created with base cell size of 0.1m resolution for all the snippet lines in order to check the data coverage of each snippet modes. Respective snippet mosaics in the SGU were classified into five classes according to the intensity levels (unsupervised classification).

## **3.0 RESULTS AND ANALYSIS**

Visual, data density comparisons, intensity profiles and intensity volume comparisons were carried out on the respective mosaics to check the radiometric and geometric distortions during the analysis.

### **3.1 Visual Comparison of the Images**

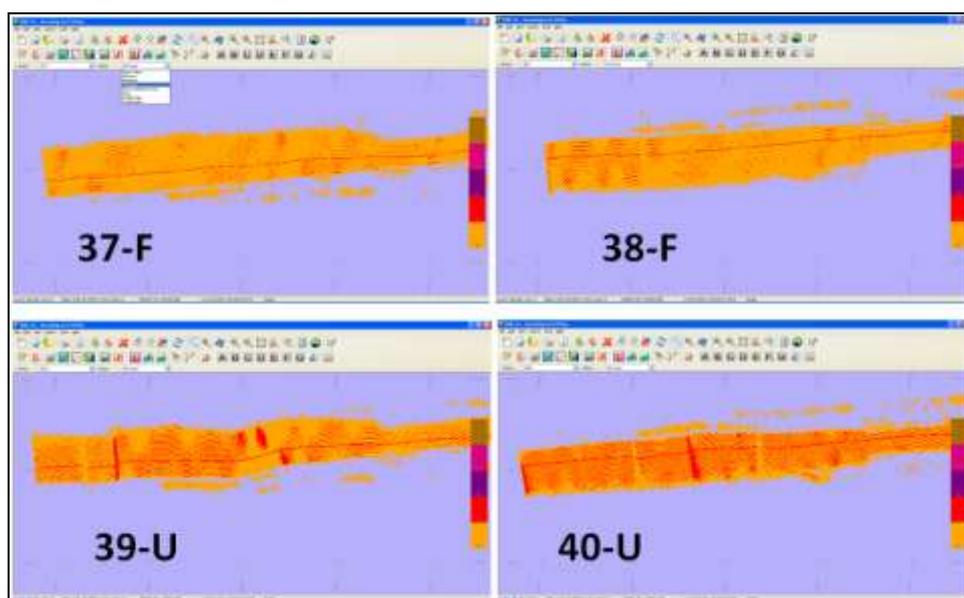
The classified snippet images are shown in the Figure 1 on the same scale. Lines 37 and 38 are flat bottomed and lines 39 and 40 are uniform-bottomed snippet. Results show that all the four images are visually almost identical. This implies that even though the flat and the uniform modes are two bottom assumption techniques, not much difference can be seen in the final seabed classification.



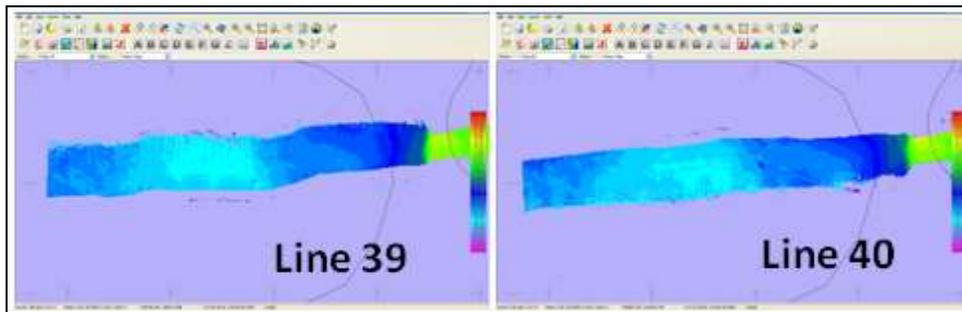
**Figure 1:** Different snippet mode imageries over the same seabed area

### 3.2 Geometry Comparison

Here the classified snippet mosaic images were analysed for spatial data coverage. Snippet data density or the hit counts per unit cell area was computed for each line in the corresponding SGU layers. Red colour indicates the high density data areas. There are more red coloured areas in the uniform-bottom lines than that of the flat-bottom mode lines (Figure 2). The overall snippet data density (data coverage) for flat-bottom and uniform-bottom modes is different for the same area. Uniform-bottom mode gave more dense data than in the flat-bottom mode in the areas where the slope of the swath is un-uniform. This can be verified by referring to the bathymetric data of the survey lines (Figure 3).

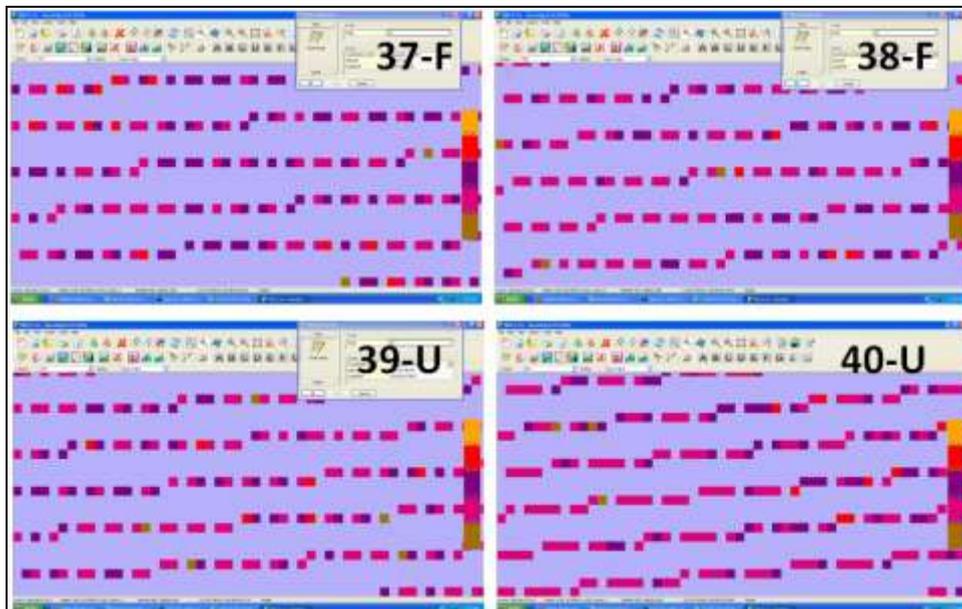


**Figure 2:** Hit count for the snippet data lines



**Figure 3:** Bathymetry for survey lines

Furthermore, several sample test areas on flat and slope areas of the survey lines were chosen in the sounding grid mosaic of 0.1m cell size for further analysis of the data density. Results for the same flat and sloped areas are shown in Figure 4 and Figure 5 respectively on the same scale. Here in both sample areas, the flat-bottom mode gave more gaps compared to the uniform-bottom mode.



**Figure 4:** Data coverage in flat sample area for different lines in 0.1m mosaic

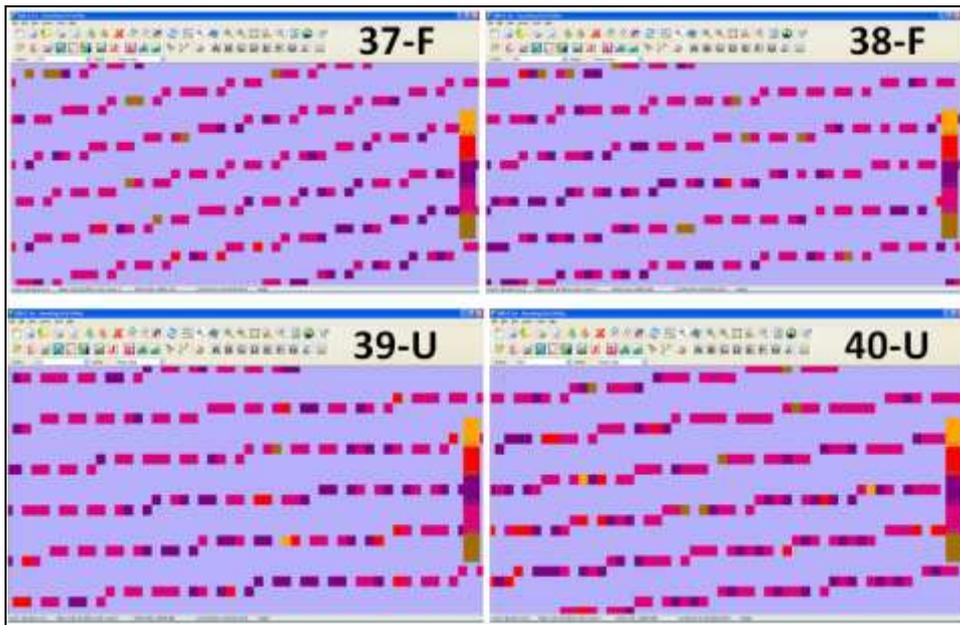


Figure 5: Data coverage in sloped sample area for different lines in 0.1m mosaic

### 3.3 Radiometry Comparison

Respective mosaic sets were compared for the classification accuracy based on intensity profile and intensity volume comparison by selecting some flat and slope sample areas. Intensity profiles were obtained by drawing profiles over the sample areas of the snippet images in SGU. For one reference line, the corresponding intensity profiles were obtained with the appropriate layer combination. Figure 6 shows the selected overall along track intensity profiles. The upper graph is for the same modes (37F vs 38F) and the lower graph is for different modes (38F vs 39U).

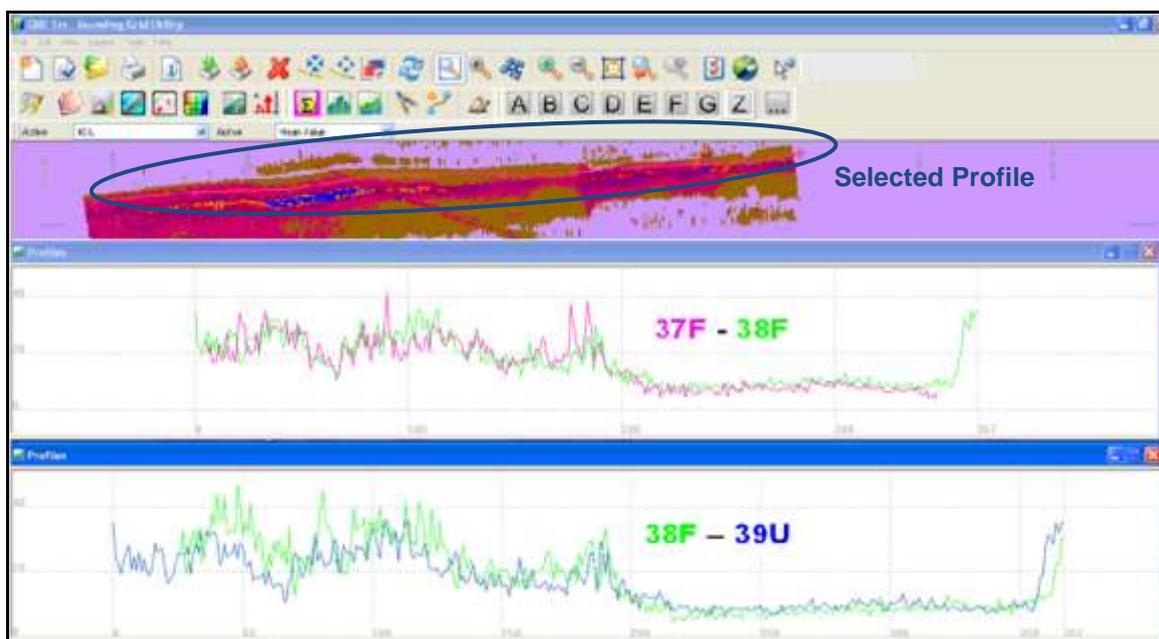
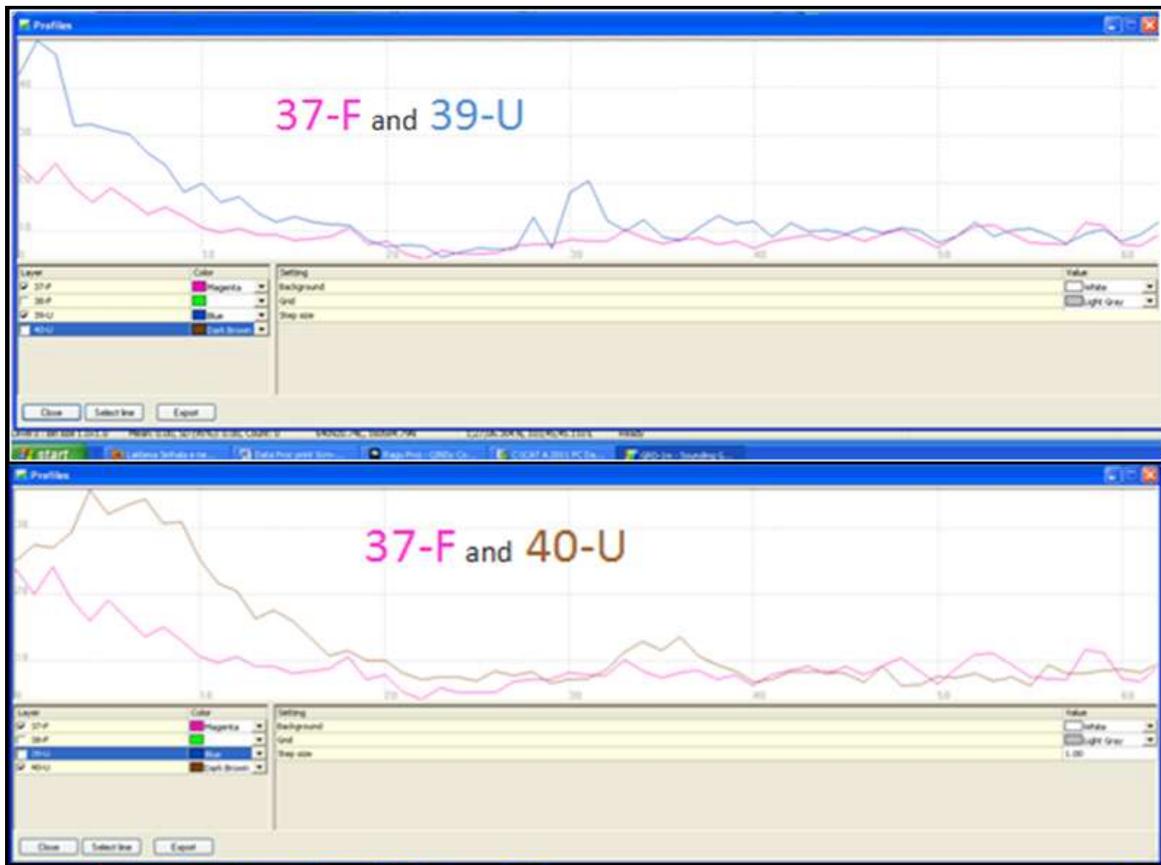


Figure 6: Overall along track intensity profile comparison

The intensity profile patterns are almost the same in either case. However, the differences are higher on the slope areas between different modes. Therefore another intensity profile matching was also carried out between the different snippet modes on identified slope-to-flat sample areas on a higher scale (Figure 7). Here, it is obvious that there is a clear difference in the intensity between the snippet modes on the slope areas than the flat seabed areas.



**Figure 7:** Intensity profile comparison on slope-to-flat area with different snippet modes

Finally, the intensity volume differences are computed over the selected flat and sloped sample areas of the snippet images using the SGU tool in QINSy software and the analysis were carried out based on the differences between the average layer intensities over the sample area. The numbers of sample areas are selected having different snippet mode line combinations and the results are summarised in Table 1. For the same snippet mode (flat-flat or uniform-uniform), the average intensity differences are less in both flat and slope areas. Where as in the different snippet modes case (flat-uniform), it gave a higher difference in slope areas than that of the flat areas. However the differences are greater between the different snippet modes than the same snippet modes even on the flat areas.

**Table 1:** Average intensity between line combinations

| <b>Id</b> | <b>Flat</b> | <b>Slope</b> | <b>Layer-1 Line</b> | <b>Layer-2 Line</b> | <b>Layer-1 Intensity<br/>(intensity unites)</b> | <b>Layer-2 Intensity<br/>(intensity unites)</b> | <b>Difference<br/>(intensity unites)</b> |
|-----------|-------------|--------------|---------------------|---------------------|---|---|--|
| 1         | √           |              | 38-F                | 37-F                | 7.24  | 7.26  | 0.02                                     |
| 2         | √           |              | 39-U                | 40-U                | 8.23  | 8.29  | 0.06                                     |
| 3         |             | √            | 38-F                | 37-F                | 12.34   | 12.57   | 0.24                                     |
| 4         |             | √            | 39-U                | 40-U                | 13.54   | 13.67   | 0.13                                     |
| 5         | √           |              | 39-U                | 37-F                | 8.37  | 7.23  | 1.14                                     |
| 6         | √           |              | 39-U                | 37-F                | 15.58   | 15.91   | 0.33                                     |
| 7         | √           |              | 39-U                | 38-F                | 15.58   | 14.77   | 0.81                                     |
| 8         | √           |              | 40-U                | 38-F                | 9.04  | 8.75  | 0.29                                     |
| 9         | √           |              | 40-U                | 37-F                | 15.99   | 15.91   | 0.08                                     |
| 10        | √           |              | 40-U                | 37-F                | 14.69   | 14.13   | 0.56                                     |
| 11        |             | √            | 39-U                | 37-F                | 13.43   | 3.03  | 10.40                                    |
| 12        |             | √            | 39-U                | 37-F                | 1.79  | 14.17   | 12.38                                    |
| 13        |             | √            | 39-U                | 38-F                | 13.38   | 18.05   | 4.67                                     |
| 14        |             | √            | 40-U                | 38-F                | 13.67   | 18.74   | 5.07                                     |
| 15        |             | √            | 40-U                | 38-F                | 15.99   | 14.77   | 1.22                                     |
| 16        |             | √            | 40-U                | 37-F                | 10.98   | 8.92  | 2.06                                     |

Table 2 summarises the maximum and minimum intensity differences for the selected sample areas and their average intensity differences. The average intensity difference is 5.97 unites for the slope areas and 0.54 unites on the flat areas. These results confirmed that, there is a significant difference between the snippet data modelling modes on the slope areas. However the difference is higher in the different mode combination (0.54 unites) than in the same modes (0.11 unites). In each bottom assumption mode, it models the snippet by its own way. The effect is not high for the flat areas and that is why there is a higher difference in the combination results than the same modes. But when it comes to the slope areas, the different is greater because the flat assumption cannot model the slope terrain as in the uniform mode.

**Table 2:** Statistical comparison analysis for flat and slope areas

| <b>Snippet Modes</b> | <b>Area</b>  | <b>Maximum Difference<br/>(intensity unites)</b> | <b>Minimum Difference<br/>(intensity unites)</b> | <b>Mean<br/>(intensity unites)</b> |
|----------------------|--------------|--|--|------------------------------------|
| Different mode       | Flat         | 1.14   | 0.08   | 0.54                               |
|                      | Slope        | 12.38  | 1.22   | 5.97                               |
| Same mode            | Flat & Slope | 0.24   | 0.02   | 0.11                               |

#### 4.0 CONCLUSION

The results from both flat and uniform bottom assumption techniques are nearly similar in overall seabed classification. This concludes that the use of snippet mode techniques does not make significance difference in the final bottom classification. However in the slope and undulated areas, the mean difference is 5.97 and for the flat areas, it is 0.54 units. This concludes that the difference in slope areas is slightly greater than in the flat areas. The reason for this effect is because in the flat bottom, it assumes that seabed is completely flat

and the uniform mode assumes it is uniformly sloped. But the actual seafloor is ideally not flat or uniform. Therefore, in both modes, the calculated backscatter incidence angles and calculated ensonified area are incorrect. This will create radiometric and geometric distortions in the final image. Snippet uniform mode in RESON SeaBat 8124 MBES assumes that seafloor is uniformly slanted with the ratio of 1/16 into range. For shallow depths like 0-20m, it will not affect much in modelling of the actual seafloor as in this study area. It gave similar results in both flat and uniform mode snippet images. Therefore a surveyor can use any bottom technique for simple applications where less accuracy and reliability is accepted as in the reconnaissance surveys, etc.

## 5.0 RECOMENDATIONS

It is clear that both of the snippet modes are not capable of modelling the actual seabed. However, with the multibeam bathymetry data, one can reconstruct the actual seabed topography. Therefore with the combination of the bathymetry data and backscatter data will provide more accurate results in snippet data modelling. In this study, the survey area was small and with not much undulation. Therefore it is recommended to carry out a comprehensive study in a larger area covering different bottom types with highly undulated seabed.

In this study, it is not expected to compare the final results with the true seabed interpretation as it is a merely a comparative study between the two techniques based on the unsupervised classification. However for true bottom interpretation, TVG and beam pattern corrections must be considered and it is recommended to use advance software in backscatter processing and bottom interpretation. Bottom samples or underwater photographic techniques must be used to verify the results.

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