An Aid in Determining the Territorial Sea Baseline using Satellite-Derived Bathymetry

Kelvin Kang Wee TANG, Mohd Razali MAHMUD, Malaysia;
Alhaji HUSSAINI and Auwal Garba ABUBAKAR, Nigeria

Key words: Baseline Delineation; Territorial Sea Baseline; Marine Cadastre

SUMMARY

In Malaysia, the marine jurisdiction and administrative power over its marine environment is split between the federal government and local coastal states' government. According to Territorial Sea Act 2012 [Act 750], three nautical miles from the low-water line of the ordinary spring tides falls under the coastal states' government. Whilst, the federal government has the jurisdiction and management responsibility beyond the three nautical miles limits up to the outer edge of the Exclusive Economic Zone and continental shelf. Malaysia has initiated the marine cadastre system to register the rights, interests and ownership of spatially determined parcels in the context of the marine environment Yet, there is no proper guideline and marine policy been made as there are many issues regarding intrinsic technical and legal aspects need to be resolved. As a governmental agency who is responsible in the nation's boundary limits survey and maps publication, Department of Survey and Mapping Malaysia has commenced a detailed national territorial sea baseline survey using vessel-based acoustic method in 1998. Thus, a total of 159 base points for baseline determination has been filed and eventually enacted under the Baseline of Maritime Zones Act 2006 [Act 660]. Nonetheless, the baseline position at a particular time may never be the same and thus very soon become obsolete. In regard to this issue, it is essential to understand the issue of shifting marine baselines which occur either gradually or in sudden due to human activities or natural morphology alteration. The presence of satellite-derived bathymetry has brought in new revolution in hydrography. With proper calibration and bathymetry inversion model, accurate depths can be yielded from high-resolution multispectral imagery. Therefore, satellite-derived bathymetry approach here can be an efficient and repeatable way to derive the seabed topography along huge segments of coastline. The study suggests that satellite-derived bathymetry approach can be recognised as an aid in determining the baseline to support marine cadastre initiative.

An Aid in Determining the Territorial Sea Baseline using Satellite-Derived Bathymetry

Kelvin Kang Wee TANG, Mohd Razali MAHMUD, Malaysia;
Alhaji HUSSAINI and Auwal Garba ABUBAKAR, Nigeria

1. INTRODUCTION

Since the last decade, the rapid development activities run not limited in land, but also go off towards the coastal and offshore region. It conveys the reform of our cadastral surveying system over many progressively-developed nations around the world, including Malaysia. In fact, Department of Survey and Mapping Malaysia (DSMM) has initiated the marine cadastre system to register the rights, interests and ownership of spatially determined parcels in the context of the marine environment (Teo & Fauzi, 2006), yet the implementation of the marine cadastre is still at the rudimentary stage. To date, there are many issues regarding intrinsic technical and legal aspects need to be resolved (Ashraf, 2004; Ashraf *et al.*, 2014; Nazirah & Abdullah, 2014).

Similar to land title registration system, marine cadastre is simple a cadastre system in the context of the marine environment which records the right, interests and ownership of spatially a determined marine parcels respectively. In land cadastral surveying, physical boundary markers are planted on site and charted in legal documents such as topographic maps and certified plans. Conversely, the territorial sea baseline (TSB), the low-water line along the coast is neither delimited nor demarcated. The marine boundaries are usually only exist virtually but not visible in actual position. Normally, the baseline from which the territorial sea is measured from the low-water line along the coast as marked on large scale 2D map or visualised through 3D GIS system.

Coastal region is an area of encounter between land and sea or ocean, where interaction of the sea and land processes occurs. These areas are mostly occupied with high density of population due to its economic and activities. Changes in the coastal area can be related to human's activities or natural morphology alteration which occur either gradually or in sudden. Likewise, seabed topography at a particular time may be never the same and thus very soon become obsolete. In regard to this issue, it is essential to understand the issue of shifting marine baselines which occur either gradually or in sudden due to human activities or natural morphology alteration.

For instance, satellite-derived bathymetry (SDB) is gaining acceptance for daily use, not only as an operational exploration tool, but as a new technique that is capable of providing calibrated and validated depths to the marine cartographer. In short, it has the potential to provide a key solution to updating charts over coastal waters that experience rapid seabed changes and in areas where little or no existing hydrographic data exists.

2. DETERMINING THE SEA BASELINE - MEASUREMENT ASPECT

In line with the provision of United Nations Convention on the Law of the Sea (UNCLOS), Malaysia's marine jurisdiction and administrative power over its marine environment is split between the federal government and local coastal states' government. In fact, the foreshore maritime jurisdiction is splits into two, within the three nautical miles from the low-water line of the ordinary spring tides falls under the coastal states' government while the remainder belongs to the federal government. Coastal states within Malaysia have the absolute jurisdiction over their coastal water. Whilst, the federal government has the jurisdiction and management responsibility beyond the three nautical miles limits to the outer edge of the Exclusive Economic Zone (EEZ) and continental shelf as stipulated in Territorial Sea Act 2012 [Act 750].

For land boundary, the buried boundary markers are placed physically static to depict the borders of the surveyed land parcels on the ground. On contrast, to monitor and manages the maritime territories, there are certain difficulties as the boundaries are not demarcated. In the context of maritime boundary administrative power, it is important to delineate the maritime baseline precisely and keep it up-to-date to safeguard its international maritime boundary sovereignty as well as its local states' marine cadastre jurisdiction. As a governmental agency who is responsible in the nation's boundary limits survey and maps publication, DSMM has commenced a detailed national TSB survey using vessel-based acoustic method in 1998. Thus, a total of 159 base points for baseline determination has been filed and eventually enacted under the Baseline of Maritime Zones Act 2006 [Act 660]. Nonetheless, the maritime boundary is neither delimited nor demarcated. Likewise, the seabed topography and baseline position may never be the same as the time goes, which can affect the maritime jurisdictional limits.

Apparently, there is a legislative gap on the issues concerning the maritime baseline stability. Natural phenomena coupled with human's activities can alter the seabed topography and eventually causing shifting of the maritime baseline over the time, thus it brings implications to the marine cadastre implementation throughout the nation. Hence, determining the sea baseline is vital in term of maritime policy and legal aspects to support the marine cadastre initiative. Typically, hydrographic measurements are using manned vessel equipped with precise positioning system and echo sounder. However, the ultra-shallow coastal water region of down to 0 - 1 metre is almost a fruitless task for vessel-based acoustic sounding approach.

The preface of SDB has brought in new revolution in hydrography. This remote sensing and GIS-based technology is believed to be an efficient and repeatable way to derive the seabed topography along huge segments of coastline for the need of Malaysia marine cadastre initiative. The biggest challenge in DSMM now is to obtain the latest seabed topography data in creating a seamless large-scale land-to-sea topographic map and updating its marine geodetic database (MGDB). As a result, SDB is essentially a considerable approach that works best and perfect data coverage from shore to deep can be obtained.

3. DATA AND METHODOLOGY

3.1 Study Area

Malaysia is known as a maritime country with a total coastal belt length of 4,809 kilometres, varies from scenic bays flanked by rocky headlands to shallow mud flats lined with mangrove forests rich in biodiversity. This present study area (Figure 1) focused on a relatively small region (latitudes of 1°18’N to 1°21’N and longitudes of 103°34’E to 103°38’E), makes an attempt to thrive the bathymetric depths over the southwest of Johor state in Peninsular Malaysia. In term of geographical location, it lies close to the Straits of Malacca and Straits of Johor which separates two neighbouring nations, Malaysia and Singapore. Generally, this swampy region is fronted by lavish mangroves and muddy flat slopes with turbid suspended sediments.

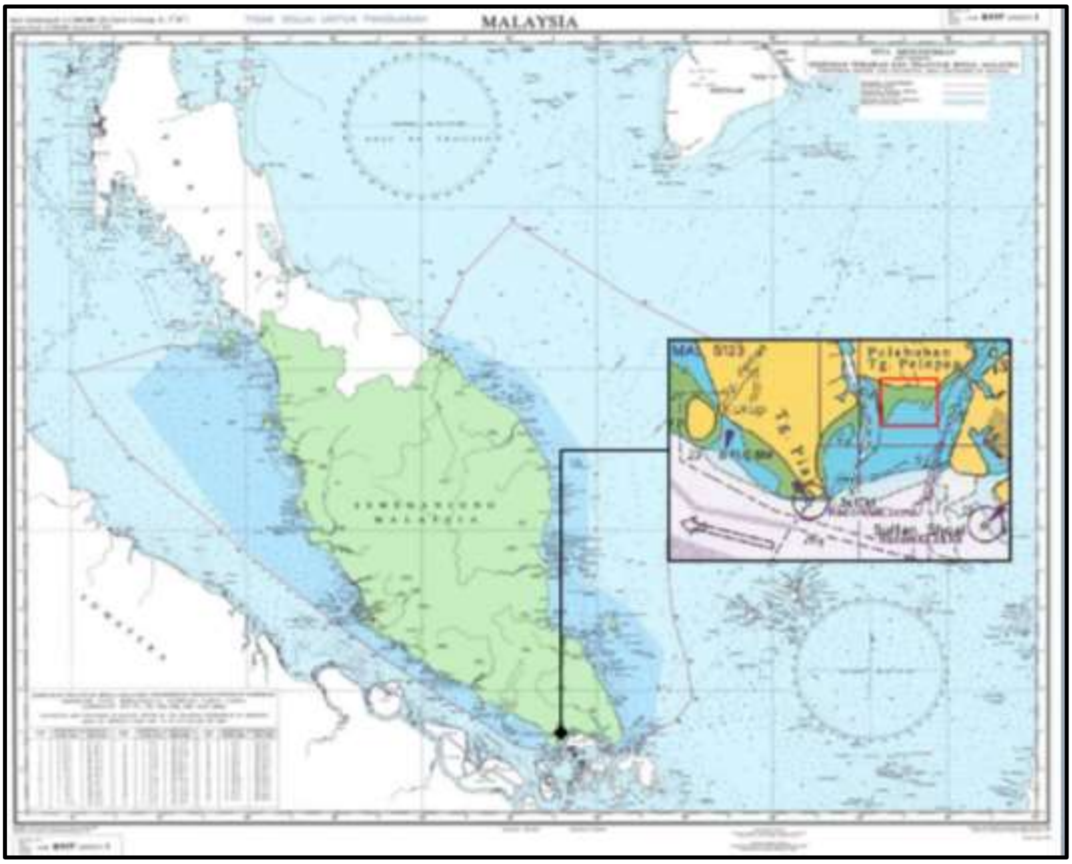

Figure 1: Coverage of the study area over the southwest of Johor state, Malaysia.

3.2 Data Source

Landsat-8 multispectral images acquired in June 2013 were utilised as in this feasibility study. These images were geo-referenced to the nautical chart by selecting a sufficient number of ground control points were widely scattered throughout the entire scene. Subsequently, those 30m resolution multispectral images were re-sampled into smaller area of which only cover the study area in order to optimize the image processing later on (Figure 2). Image pre-processing process including radiometric, atmospheric and geometric correction were then being done order to eliminate the atmospheric effects, unwanted path radiance, unnecessary sea surface reflectance as well as the distortion of the images.

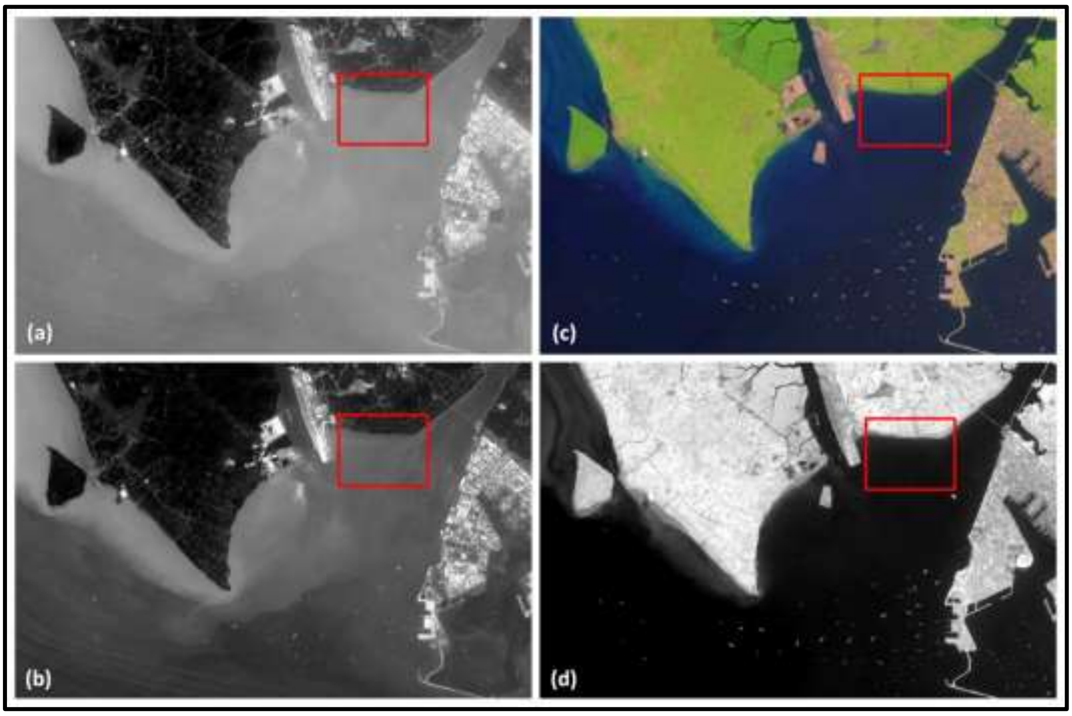

Figure 2: Landsat-8 multispectral images of the southwest of Johor state, Malaysia. Image (a) Blue (Band 2); (b) Green (Band 3); (c) True Colour (RGB); and (d) NIR (Band 5).

An echo sounding fieldwork survey was commenced in August 2013 throughout the entire study area. The bathymetric depths across the well-distributed survey planning lines with 5 metres interval and 25 metres line spacing were surveyed using small hydrographic boat fitted with single beam echo sounder synchronized with precise differential-GPS positioning. Consequently, the tidally-referenced *in-situ* bathymetric depths were used to construct the depth-retrieval algorithm and data assessment at the end of the process.

3.3 Generation of Low-water line

This study made an attempt to determine the seabed topography over the shallow coastal region via an empirical approach purposed by Dierssen *et al*. (2003). This model applies the fundamental principle of Beer-Lambert Law, intensity of light decreases exponentially with depth, to relate the observed reflectance from the optical sensor to the water depth. Theoretically, the linear inversion approach is able to empirically deriving the relationship between a pair of water-penetrating wavelengths. The estimated bathymetric depth (z) is mathematically calculated from two tuneable constant coefficients (m_0 and m_1) and a log-difference between the observed reflectance of two consecutive bands (λ_i and λ_j). Equation 1 below demonstrates the Dierssen *et al.*'s algorithm:

$$z = m_0 * \ln\left[\frac{nR_w(\lambda_i)}{nR_w(\lambda_j))}\right] + m_1 \qquad (1)$$

where
- z = depth value from derived depth
- R_w = observed reflectance value of band i and band j
- m_0 = tuneable constant to scale the ratio to depth
- m_1 = offset of a depth
- n = constant value

The bathymetric information or water depths were extracted from multispectral satellite images via Dierssen *et al*.'s log-ratio (blue/green) model. A set of measured bathymetric points was chosen for the bathymetry inversion calibration process. Least square regression analysis was then being adopted to approximate the best fit value to resolve the two unknown tuneable constants in the above-mentioned equation. The determined tuneable constants were then being inserted back into Equation 1 to construct the imagery-derived bathymetric model and being plotted into a bathymetric map.

4. RESULTS AND ANALYSIS

This section presents the initial finding and results analysis of the satellite-derived bathymetry that allows performing low-water line measurement. In order to perform visual inspection and quantify the quality of the SDB's performance, maps representing the bathymetric depths derived from remotely-sensed images were generated.

Distinctly, Figure 3 to Figure 4 below show the overall seabed topographical relief of the study area via digital elevation models (DEM) and low-water lines (zeroline) generated from the vessel-based *in-situ* survey data and SDB depths.

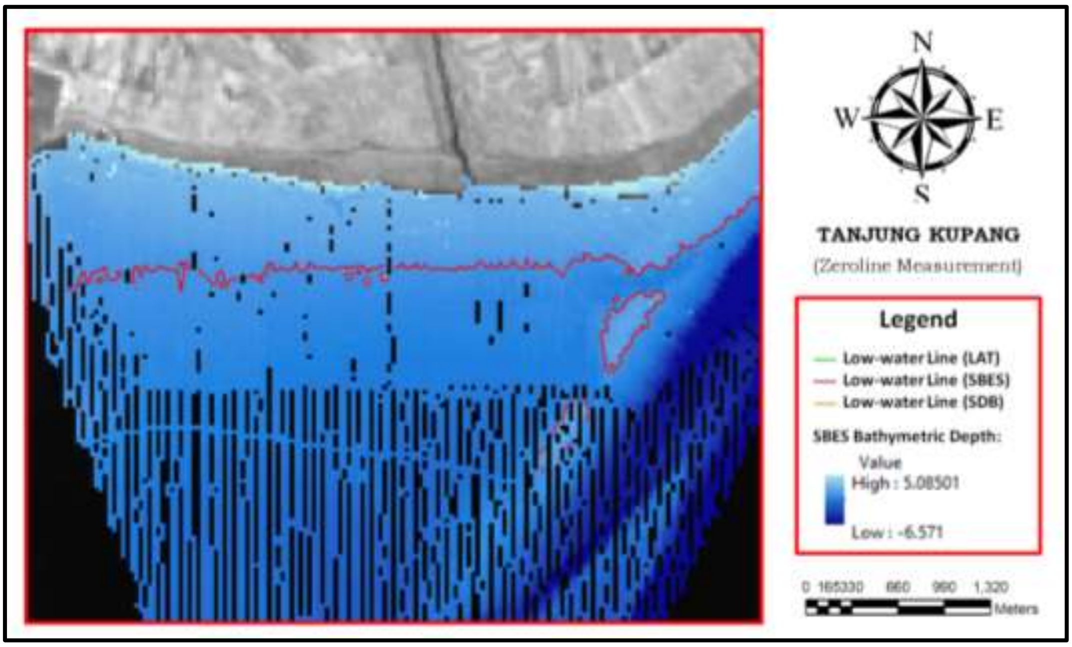

Figure 3: DEM and zeroline generated from SBES Bathymetric Data.

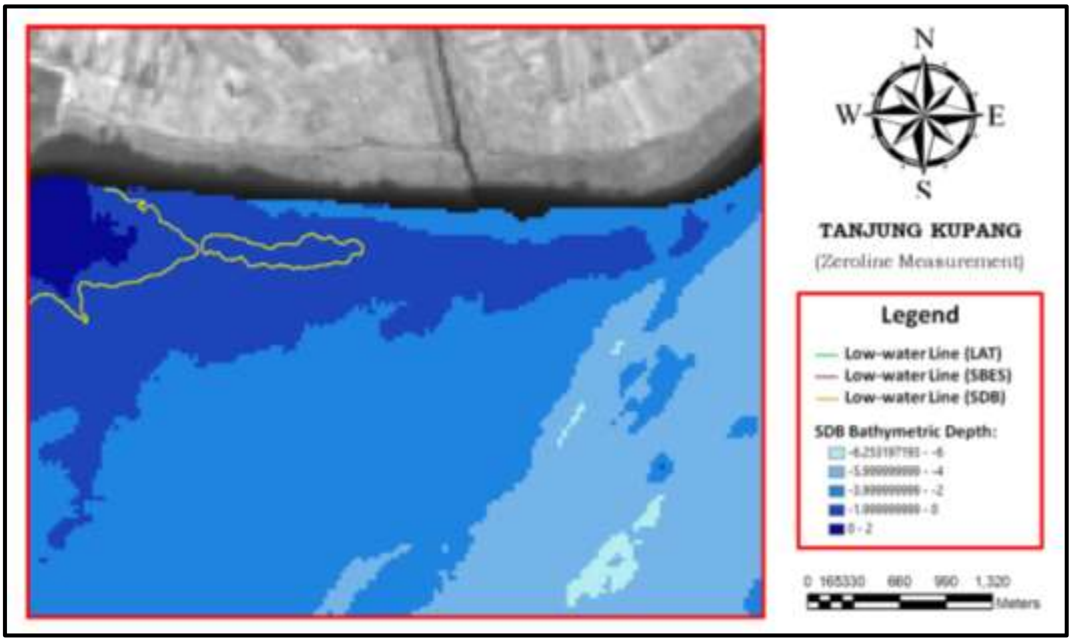

Figure 4: DEM and zeroline generated from SDB Bathymetric Depths.

In the course of identifying the coastline changes, the zero-elevation line representing the lowest astronomical tide (LAT) was extracted from nautical chart to and then overlaid on the maps to mark its original shoreline position (Figure 5). The datasets also shows the alteration of zeroline over the coastal area of Tanjung Kupang throughout the period of 1999 - 2013.

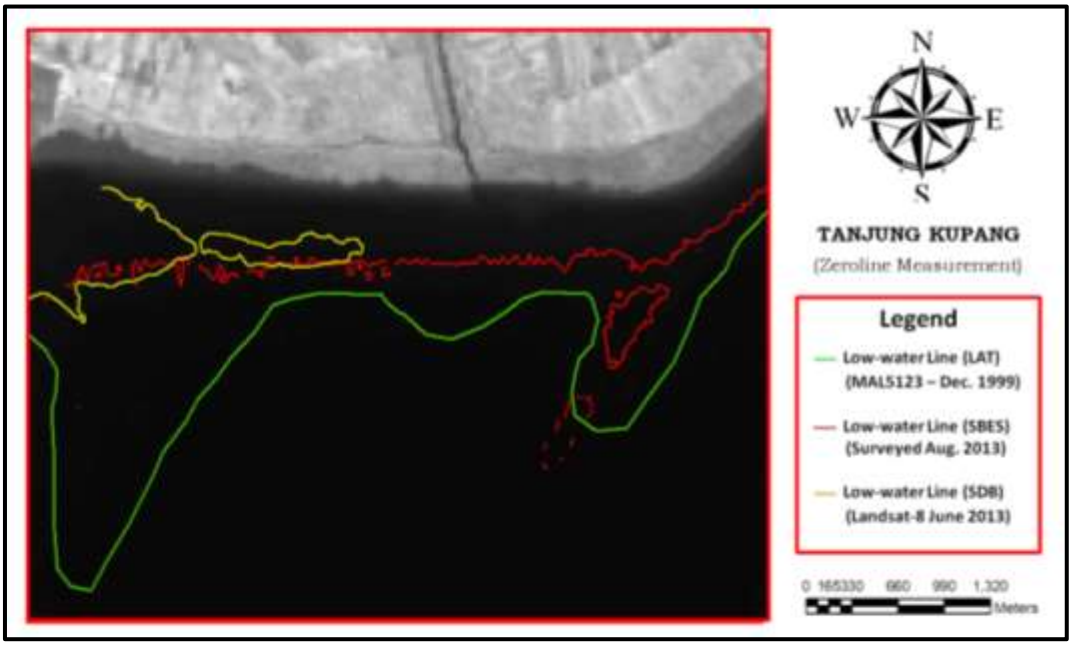

Figure 5: The map of alteration of zeroline over the coastal area of Tanjung Kupang throughout the period of 1999 – 2013.

The accuracy data assessment is an important step in the determining the usability of the manipulated data or commonly known as the quality assurance as well. Spatial and statistical analysis was carried by examining 1,367 imagery-derived bathymetric depths extracted from the SDB models against the precisely collected SBES data. Table 1 below illustrates the correlation coefficient (r) and correlation of determination achieved here.

Table 1: Statistical results based on Dierssen *et al.*'s SDB model

Dierssen et al.'s SDB Model	
Correlation of Determination (r^2)	**0.7324**
Correlation Coefficient (r)	**0.85**

Thus, further quality assessment was made with the minimum standards for hydrographic surveys as stated in International Hydrographic Organisation’s Special Publication (S-44). According to the S-44 standards, the maximum allowable total vertical uncertainties (TVU) for Special Order is within 0.25 metre, Order 1a and 1b is below 0.5 metre and approximately 1.0 metre for Order 2 within 10 metres water depth. Histogram graph in Figure 6 below illustrates the distribution of depth differences from both Dierssen’s model. The x-axis is representing the error values, while the y-axis is showing the number of samples count. The outcomes are also arranged according to IHO S-44 survey order classes in histogram graph respectively. In term of percentage achievement, 88.5 percent (1210 samples) generated from Dierssen *et al.*’s model have passed the minimum IHO survey standards within the Order 2 specification; meanwhile, 11.5 percent (156 samples) have failed to comply the minimum requirement established in IHO’s S-44, respectively.

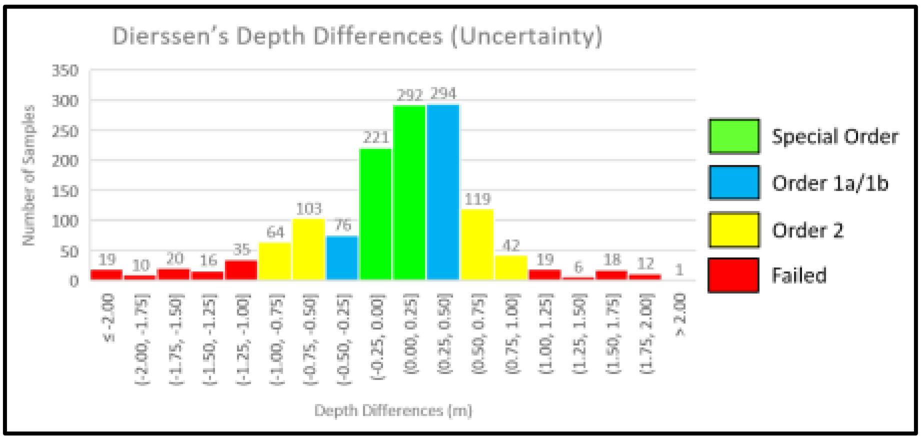

Figure 6: Distribution of depth differences and survey class achievements from Dierssen *et al*.’s model.

5. CONCLUSION

This study examines usability of SDB approach to extract bathymetric information and eventually determine the low-water line in the southwest of Johor state in Malaysia. In general, this study has enlightened that the SDB’s empirical approach is possible to provide realistic seabed terrain profiles and three-dimensional quantitative information on shoreline position. Although satellite-derived bathymetric mapping is an innovative solution to supplement the traditional vessel-based survey techniques, yet, it can be consider as an alternative tool in determining the low-water line at the ultra-shallow water areas, which are often inaccessible for vessel-based acoustic sounding approach.

ACKNOWLEDGEMENTS

The authors would like to thank the Department of Survey and Mapping Malaysia (DSMM), Ministry of Water, Land and Natural Resources (KATS); GeoCoastal Research Unit, Geospatial Imaging and Information Research Group (GI2RG); and Faculty of Built Environment and Surveying (FABU), Universiti Teknologi Malaysia (UTM). This research would not have been possible without their technical supports and financial aids under Research University Grant (Vote Number: Q.J130000.2527.17H97).

REFERENCE

Abdullah, A., Omar, A. H., Chan, K. L., Mat Arof, X., Jamil, H., & Teng, C. H. (2014). *The development of marine cadastre conceptual model for Malaysia*. Paper presented at FIG Congress 2014, Kuala Lumpur, Malaysia.

Bramante, J. F., Raju, D. K., & Sin, T. M. (2013). Multispectral derivation of bathymetry in Singapore's shallow, turbid waters. *International journal of remote sensing*, *34*(6), 2070-2088.

Dierssen, H. M., Zimmerman, R. C., Leathers, R. A., Downes, T. V., & Davis, C. O. (2003). Ocean color remote sensing of seagrass and bathymetry in the Bahamas Banks by high-resolution airborne imagery. *Limnology and Oceanography, 48*(1part2), 444-455.

Gao, J. (2009). Bathymetric mapping by means of remote sensing: methods, accuracy and limitations. *Progress in Physical Geography, 33*(1), 103-116.

Hamylton, S. M., Hedley, J. D., & Beaman, R. J. (2015). Derivation of high-resolution bathymetry from multispectral satellite imagery: a comparison of empirical and optimisation methods through geographical error analysis. *Remote Sensing*, *7*(12), 16257-16273. doi:10.3390/rs71215829

Jawak, S. D., Vadlamani, S. S., & Luis, A. J. (2015). A synoptic review on deriving bathymetry information using remote sensing technologies: models, methods and comparisons. *Advances in Remote Sensing, 4*(02), 147.

Nazirah, M. A. & Abdullah, H., O. (2014). Developing boundary demarcation guideline for marine cadastre survey. *Buletin Geospatial Sektor Awam*. Edisi 2/2014, 21-29.

Pacheco, A., Horta, J., Loureiro, C., & Ferreira, Ó. (2015). Retrieval of nearshore bathymetry from Landsat 8 images: a tool for coastal monitoring in shallow waters. *Remote sensing of environment, 159*, 102-116.

Pe'eri, S., Parrish, C., Azuike, C., Alexander, L., & Armstrong, A. (2014). Satellite remote sensing as a reconnaissance tool for assessing nautical chart adequacy and completeness. *Marine Geodesy, 37*(3), 293-314. doi:10.1080/01490419.2014.902880

Said, N. M., Mahmud, M. R., & Hasan, R. C. (2017). Satellite-derived bathymetry: Accuracy assessment on depths derivation algorithm for shallow water area. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences, 42*.

Sánchez-Carnero, N., Ojeda-Zujar, J., Rodríguez-Pérez, D., & Marquez-Perez, J. (2014). Assessment of different models for bathymetry calculation using SPOT multispectral images in a high-turbidity area: the mouth of the Guadiana Estuary. *International journal of remote sensing, 35*(2), 493-514.

Stumpf, R. P., Holderied, K., & Sinclair, M. (2003). Determination of water depth with high-resolution satellite imagery over variable bottom types. *Limnology and Oceanography, 48*(1), 547-556.

Su, H. B., Liu, H. X., & Heyman, W. D. (2008). Automated derivation of bathymetric information from multi-spectral satellite imagery using a non-linear inversion model. *Marine Geodesy, 31*(4), 281-298. doi:Pii 90637241710.1080/01490410802466652

Tang, K. K. W. and Mahmud, M. R. (2018). Imagery-derived bathymetry in strait of johor’s turbid waters using multispectral images, *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XLII-4/W9, 139-145, https://doi.org/10.5194/isprs-archives-XLII-4-W9-139-2018, 2018.

Zheng, G., Chen, F., & Shen, Y. (2017). Detecting the water depth of the South China Sea reef area from WorldView-2 satellite imagery. Earth Science Informatics, 10(3), 331-337.

BIOGRAPHICAL NOTES

Kelvin Tang Kang Wee is an Assistant Director of Survey in Department of Survey and Mapping Johor, Malaysia. He received his B. Eng. (Geomatics) (Hons.) from Universiti Teknologi Malaysia (UTM) and Master of Remote Sensing & GIS from Universiti Putra Malaysia (UPM). He is currently Member of Royal Institution of Surveyors Malaysia (RISM) and Professional Member of Institution of Geosptial and Remote Sensing Malaysia (IGRSM). Presently, he is on full-time study leave pursuing his Ph.D (Hydrography) in UTM. His area of interest is marine positioning and hydrographic surveying using satellite remote sensing approach.

CONTACTS

Sr Kelvin Tang Kang Wee
Department of Survey and Mapping Malaysia
Department of Survey and Mapping Johor
7th-9th Floor, Block A, Wisma Persekutuan
Jalan Ayer Molek
80000 Johor Bahru
MALAYSIA

Email : kelvin@jupem.gov.my
tkwkelvin2@live.utm.my