


ELLIPSOIDALLY REFERENCED SURVEYING TECHNIQUE

A Review of the Current Status and Development of Ellipsoidally Referenced Surveying Technique in the Coastal and Offshore Zones for Hydrographic Survey Practice

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Abstract

Technologies sophistication in addition to the Industry 4.0 trend has contributed to the high-accuracy ellipsoidal height from the Global Navigation Satellite System (GNSS) to be used in hydrography for vertical positioning. The method known as Ellipsoidally Referenced Surveying (ERS) provides direct measurement of sea floor to the ellipsoid and a translation of the reference from the ellipsoid to the precise geoid or chart datum. This article is an attempt to review the nations which have adopted ERS technique for hydrographic survey practice. A few case studies on practicing ERS technique are summarised to determine the ability of this technique. Future outlooks are also discussed on realising the ERS technique in Malaysia and the role of agencies in supporting the ERS realisation. In conclusion, adopting this technique will modernise and indirectly challenge the new norm in hydrographic surveying practice in Malaysia.

Keywords: Ellipsoidally Referenced Surveying, Vertical Separation Model, Hydrographic Survey, GNSS Positioning, Satellite Altimetry, Tidal Modelling

Résumé

La sophistication des technologies, en plus de la tendance Industry 4.0, a contribué à ce que la hauteur ellipsoïdale de haute précision issue du système mondial de navigation par satellite (GNSS) soit utilisée en hydrographie pour le positionnement vertical. La méthode connue sous le nom de levés référencés à l’ellipsoïde (ERS) fournit des mesures directes du fond marin à l’ellipsoïde et une translation précise de la référence de l’ellipsoïde par rapport au géoïde ou au zéro des cartes. Le présent article décrit une tentative de passer en revue les nations qui ont adopté la technique ERS pour la pratique des levés hydrographiques. Quelques cas d’étude sur la pratique des levés ERS sont résumés afin de déterminer les capacités de cette technique. De futures perspectives font également l’objet de discussions quant à la réalisation de la technique ERS en Malaisie, ainsi qu’au rôle des agences à l’appui de la réalisation de l’ERS. En conclusion, l’adoption de cette technique modernisera et défiera indirectement la nouvelle norme en matière de pratique hydrographique en Malaisie.

Mots clés : Levés référencés à l'ellipsoïde, modèle de séparation verticale, levés hydrographiques, positionnement à l'aide du système mondiale de navigation par satellite (GNSS), altimétrie par satellite, modélisation des marées.

Articles

Resumen

La sofisticación de las tecnologías*, además de la tendencia de la Industria 4.0, han contribuido a que la altura elipsoidal de alta precisión del Sistema Mundial de Navegación por Satélite (GNSS) sea utilizada en la hidrografía para el posicionamiento vertical. El método conocido como Levantamientos referenciados elipsoidalmente (ERS) proporciona una medición directa del fondo marino al elipsoide y una traducción de la referencia a partir del elipsoide al geoide preciso o al datum de cartas. Este artículo es un intento de revisar las naciones que han adoptado la técnica ERS para la práctica de los levantamientos hidrográficos. Se resumen algunos estudios de casos sobre la práctica de la técnica ERS para determinar la capacidad de esta técnica. También se examinan las perspectivas futuras de la realización de la técnica ERS en Malasia y el rol de las agencias en el apoyo a la realización de la ERS. En conclusión, la adopción de esta técnica modernizará y desafiará indirectamente a la nueva norma en la práctica de los levantamientos hidrográficos en Malasia.

Palabras clave: Levantamiento referenciado elipsoidalmente, Modelo de Separación Vertical, Levantamiento Hidrográfico, Posicionamiento GNSS, Altimetría Satelital, Modelización de las Mareas

1. Introduction

Hydrographic surveying deals with depth determination at particular known areas normally for the purpose of creating bathymetry maps of water bodies. Historically, the mandate of soundings has come from the need to chart hazards for navigation (Smith and Sandwell, 2004). The first hydrographic technique used in determination of water depth was the sounding line which was replaced by acoustic sounding techniques (Elhassan, 2015). Also, in the past, locations of sounding depth were determined using shore-based surveying or conventional navigation technique (Berber and Wright, 2016). With the advancement of technology, the development of accurate satellite-based survey methods uses the Global Navigation Satellite System (GNSS) methodology to provide depth measurement positions.

In recent years, GNSS has been used in hydrographic surveying over horizontal positioning. However, it is believed that International Federation of Surveyors (FIG) Publication Number 62 was designed to assist in the grasping of the Ellipsoidally Referenced Surveying (ERS) technology. Mills and Dodd (2014) stated that it is primary concern that the whole phases of ERS to be understood comprehensively. In the case for vertical positioning, high accuracy GNSS processing techniques should be used as the benefit of this vertical positioning, in which the sea surface, water column and sea floor are referenced directly to a mathematically derived reference ellipsoid. High accuracy GNSS positioning techniques for vertical positioning of hydrographic survey works known as Ellipsoidally Referenced Surveying (ERS) has been utilised by the hydrographic survey community. This technique works as the features are referenced directly to a mathematical surface (ellipsoid) established from high accuracy GNSS observations and provide a translation of reference from the ellipsoid to the geoid or chart datum. Most of the organisations utilising ERS methods have established their own Standard Operating Procedures (SOPs) through in-house practice as well as trial and error research. The abundance of knowledge that is being utilised by the organisations can assist to promote a series of desirable practices for hydrographic industry. Few concerns need to be taken into account in executing ERS technique such as data acquisition from high accuracy GNSS, high accuracy GNSS data processing, vertical separation model (VSEP) development and application, quality assurance / quality control (QA/QC) of vertical offsets, high accuracy GNSS, motion and VSEP as well as their uncertainties. Last but not least is the data archive reference. Nevertheless, FIG Publication 62 has explained the concerns on the aforementioned. This publication also extended and updated the discussion conferred in FIG Publication 37.

While hydrographic organisations are looking forward to the use of ERS technique, the creation and verification of VSEP is a major challenge. The discovery of models to link the ellipsoid to the geoid is fairly unambiguous. The predominant issue is converting the data from geoid to the chart datum (CD). Creating an ellipsoidal height at the tidal point of the reference is the simplest approach that would create precisely observed separation (SEP) between the reference ellipsoid and chart datum. This article summarised the case studies from the countries that have adopted ERS technique. To this end, further discussion on realising the ERS technique in Malaysia will be explained and the role of agencies that support the realisation.

2. Nations that Create ERS and Case Studies

The entire ERS process must be understood comprehensively in order to enhance the potential of ERS technique for realisation in each country. Adaptation to the future employment of ERS technique in hydrographic society had caused many researchers to look more specifically at this concept. Many countries have started to look into implementing ERS technique. Here, a summary of a few organisations that have created the ERS technique are discussed.

2.1 National Oceanic and Atmospheric Administration Vertical Datum (NOAA VDatum)

In order to enhance the efficiency, precision and adaptability of survey activities, NOAA hydrographic field units have been collecting bathymetry utilising an ellipsoid reference since 2016. Subsequently, bathymetry referred to the ellipsoid may be translated either to other ellipsoids, orthometric or tidal datums provided by NOAA's Vertical Datum Transformation (VDatum) method, saving the hydrographer from depending concurrently on coastal tide gauge. A contemporary vertical datum transformation tool (VDatum) was developed by the NOAA to resolve the inconsistent datum issues.

VDatum translates geospatial data across 36 various vertical reference systems and eliminates the most important barriers to data exchange that enable simple translation of elevation data from one vertical datum to another. Generally, VDatum is constructed to vertically translate geospatial data from a range of tidal, orthometric and ellipsoid datums which enable the users to transform their data from specific horizontal or vertical references into a common system. This could also allow the fusion of various geospatial data in desired reference levels (NOAA, 2020a). VDatum models are created on a regional basis, with the objectives of seamless coverage for all-near waters in the United States. Conforming to FIG publication 62, three or four measures are required to translate the hydrographic survey data depending on which vertical datum is the data referenced during data acquisition. The measures are as follows:

i. The data must be referenced to the NAD83 primary ellipsoid.
ii. Transformation of the NAD83 ellipsoid to the NAVD88 primary orthometric datum.
iii. Transformation between NAVD88 and the Mean Sea Level (MSL)
iv. Transformation between MSL and Mean Lower Low Water (MLLW).

Successful development and implementation of the VDatum in a given geographical region is useful for a number of coastal applications (NOAA, 2020b). Existing bathymetric and topographic data can be transformed into a seamless digital elevation model (DEM) by first using VDatum to link the data to a specific vertical datum. It is also beneficial to the applications dependent on a seamless land-water DEM, such as storm surge and tsunami modelling, habitat restoration, sea level rise effect and ecosystem studies. VDatum also provides advantages on supporting the surveying on the ellipsoid which can reduce the vertical uncertainty from heave and dynamic draft as well as decouple tide measurement from survey.

2.2 Continuous Vertical Datum Separations for Canadian Waters

Canada is one of the countries involved in developing national continuous vertical datum separation models (SEPs) between GRS80 reference ellipsoid tied to the NAD83 Canadian Spatial Reference System (CSRS) geodetic frame and chart datum. The Continuous Vertical Datum for Canadian Waters (CVDCW) project was originated by the Canadian Hydrographic Service (CHS) to develop hydrographic-quality ellipsoid to CD surfaces in supporting the ellipsoid bathymetric reduction.

The main aim of CVDCW's SEP, known as Hydrographic Vertical Separation Surfaces (HySEPs), is to capture the spatial variability between stations and offshore by integrating ocean models, tidal data, sea level trends, satellite altimetry and geoid model. According to Robin et al. (2014), HySEPs will enable the use of GNSS for hydrographers and navigators as well as it is effective for oceanographers, environmental researchers, surveyors and engineers. The achievement is accomplished through selective combination of both sets of model and observational data. The sources needed include:

i. Geoid Model (CGG2013), which is utilised to determine the variation of the geoid with respect to the NAD83 ellipsoid.
ii. Dynamic ocean topography (DOT) used to bridge MSL to the geoid model.
iii. Hydrodynamic models utilised to examine variations in tidal regimes which provide an initial estimation of the difference between lower low water large tide (LLWLT) or other datum.
iv. Tidal stations (water level and GNSS observations) utilised for validating and modifying ocean model results.
v. Satellite altimetry used to provide measurement of the separation between the ellipsoid and MSL as well as to verify the geoid, DOT and SEP.

Figure 1 shows the schematic diagram of HyVSEP components and data sources. Approaches used to fill, control and modify each HyVSEP surface are dependent on three aspects, namely an underlying grid's resolution and synchronisation, a Laplacian interpolator and a smoother finite element (FE).

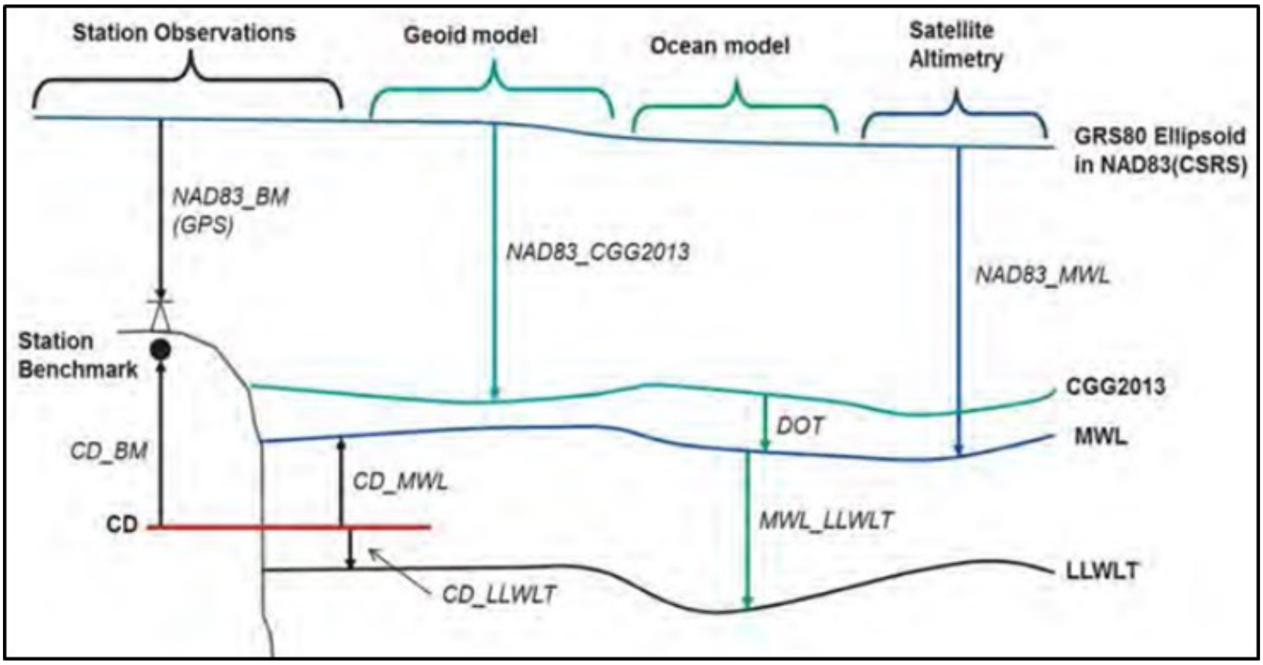

Figure 1 *Schematic diagram of HyVSEP and data sources (Robin et al., 2016)*

To this end, Robin et al. (2014) stated that HyVSEP is a modern vertical reference 3D model for the CHS. HyVSEP, especially CD surface, would enable the use of GNSS technology in data collection and increase the accuracy of nautical chart's bathymetric data. Last but not least, HyVSEP would help to link bathymetry with topography data and act as a tool to address climate change and adaptation.

2.3 Vertical Offshore Reference Frame (VORF) by United Kingdom Hydrographic Office (UKHO)

The Vertical Offshore Reference Frame (VORF) is a research project developed by collaboration between University College London (UCL) and United Kingdom Hydrographic Office (UKHO). This project started in 2005 and conveyed as a revolutionary model in 2008 for UK and Ireland. The goal of the VORF was to derive a set of models representing the locations of vertical datum surfaces with respect to a common base (GRS80 ellipsoid in ETRF89) thus enabling data to be translated from one datum to another. The vertical height information being derived in VORF model are, namely, chart datum (the reference level for nautical charts), MSL, lowest astronomical tide (LAT), highest astronomical tide (HAT), mean low water springs (MLWS), mean high water springs (MHWS), European Terrestrial Reference Frame (ETRF89), Newlyn Ordnance Datum, Poolbeg Ordnance Datum and other vertical land datum that affect the coastlines of the area concerned. Each reference frame shall be represented as a seamless surface within ETRF89 with a gridded spatial resolution of approximately 1 km. ***Figure 2*** illustrates the VORF surfaces in which land and sea datums are related to each other.

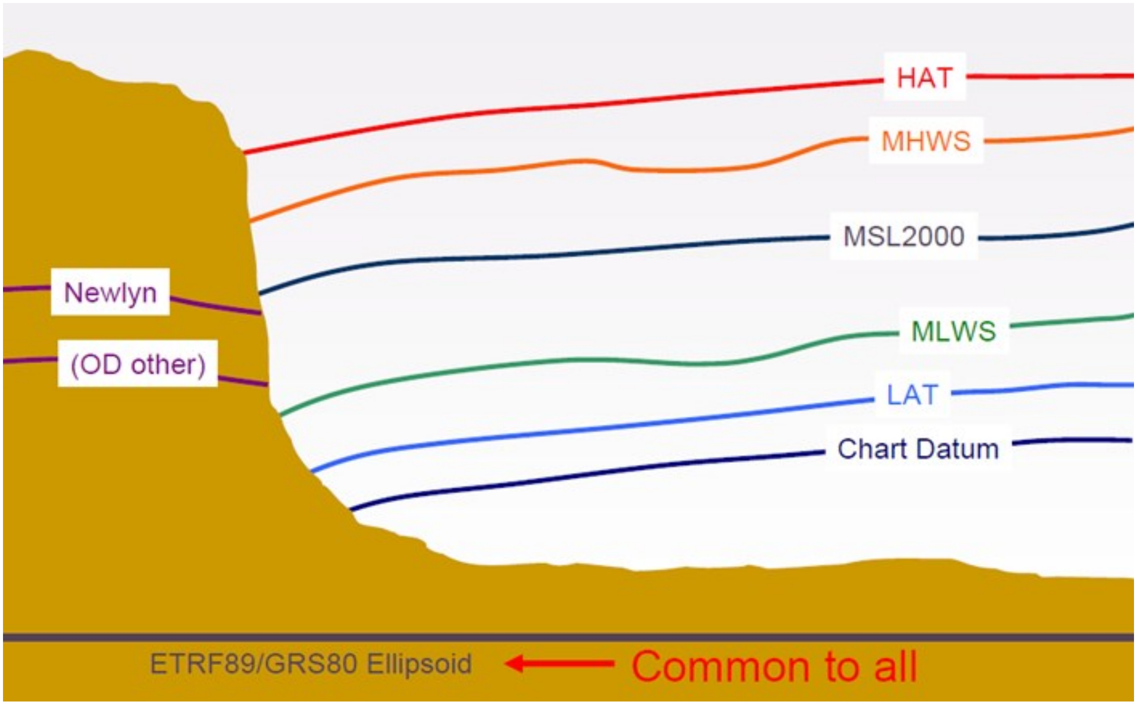

Figure 2 *VORF surface of land and sea (Ziebart & Iliffe, 2009)*

Until recently, hydrographic surveys were usually kept isolated from land surveys, and surveys at sea often used such inadequate data sets that changes in the datum were not readily possible. With the introduction of technology such as GNSS and LiDAR as well as growing interest in coastal zone areas, there is an urgent need for a system that will transform seamlessly between various reference surfaces. There are many applications which could potentially make use of the system. For instance, every vessel installed with a high precision GNSS and utilising the VORF transformation program can essentially become its own tide gauge without depending on the tide gauge observation at remote areas. It is expected to not only have a major influence in maritime safety but also important impacts of activities on operations such as hydrographic surveys.

There are several advantages in performing bathymetry data processing with VORF and GNSS.

This can increase speed of deployment where no reliance on tide gauge or requirement to transfer the chart datum. Besides, it provides rapid turnaround of surveys and rapid response to emergencies. ***Figure 3*** shows the schematic bathymetry data processing with VORF and GNSS.

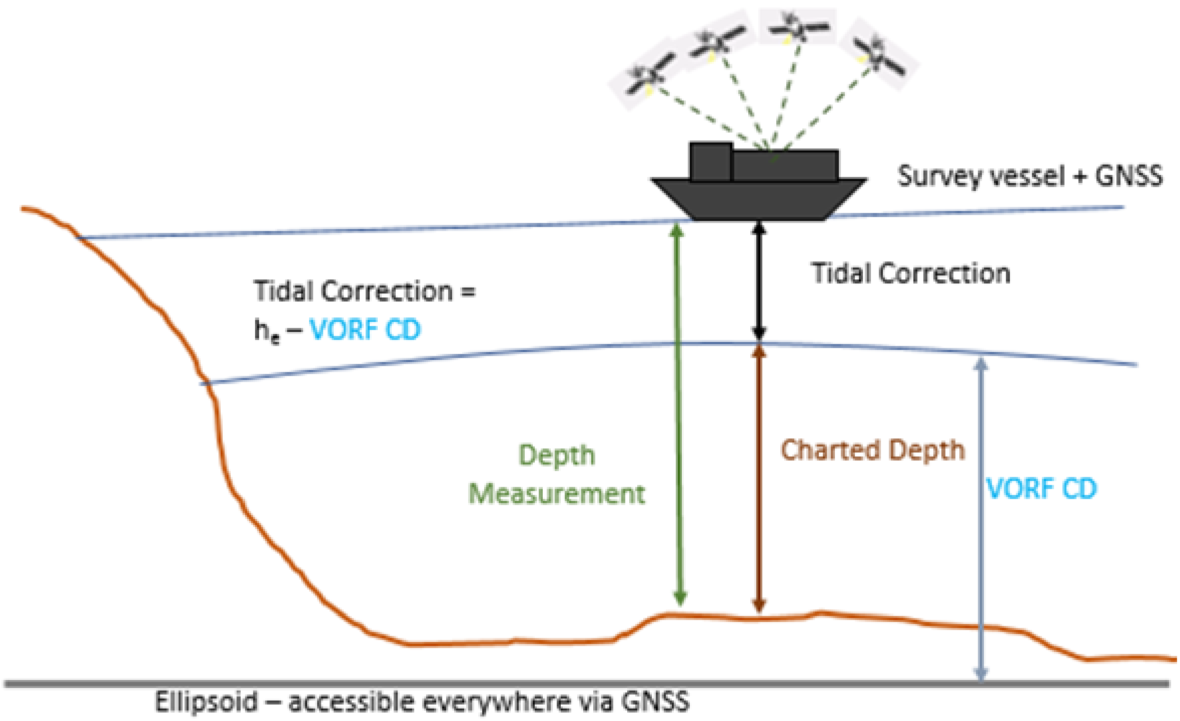

Figure 3 Bathymetry data processing with VORF and GNSS solution (adapted from Howlett, 2009)

2.4 Australian Coastal Vertical Datum Transformation (AusCoastVDT)

Australian Coastal Vertical Datum Transformation is a research project focussing on adopting an ellipsoidal based method for vertical datum transformation (VDTs). In 2004, there had been some VDT projects handled namely AUSHYDROID model. This model is supposed to assist ellipsoidal surveying at nearshore, coastal and offshore within the Australian region. AUSHYDROID would allow hydrographic surveyors and other end users to translate the geospatial data between LAT and GRS80 ellipsoid vertical datum. AUSHYDROID would also contribute several benefits to Australia's blue economy including the following:

i. Integrating bathymetry and land-based observations using a specific reference frame;

ii. Allowing regional description of coastlines and intertidal zones;

iii. Aid in the identification of territorial baselines, marine cadastre and jurisdiction claims; and

iv. To establish a benchmark for forecasts of sea level rise and climate change approach for coastal infrastructure.

According to Keysers et al. (2015), the surfaces developed in AUSHYDROID were only for the Queensland coast and serve limited datum transformation options, whereas AusCoastVDT approach employs hydrodynamic modelling and it is a national approach which allows transformation in either direction between a broad range of vertical datum. The primary aim of AusCoastVDT is to promote the development of continuous elevation data sets around the

Australian coastal region with an emphasis on the specific Australian challenges. ***Figure 4*** shows the significant vertical datums and the relationship between them. The related marine datums for AusCoastVDT are LAT, which is chart datum in Australia, MSL, MHWS and HAT. The ellipsoid based transformation approach selected uses a series of gridded surfaces, where each surface determines the separation of one vertical datum from GRS80 ellipsoid. It blends MSS and other tidal surfaces to ease and speed up the computation in implementing the vertical transformations. GRS80-AHD, GRS80-MSL, GRS80-LAT, GRS80-MHWS and GRS80-HAT are the five gridded separation surfaces produced in this project.

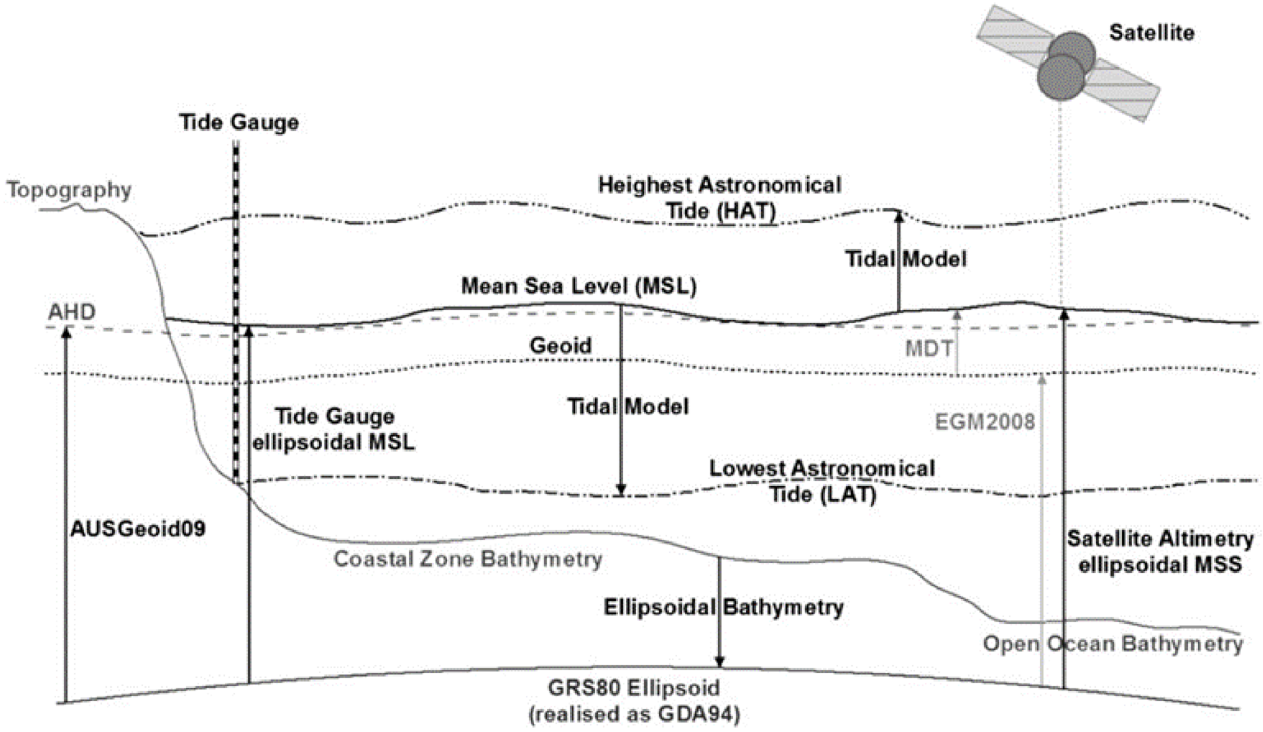

Figure 4 *Schematic depiction of ellipsoid based vertical datum transformation approach (Keysers et al. 2015)*

2.5 Miscellaneous

Substantially, more researchers have looked into the implementation of ERS technique besides the ones described earlier. Most of the Europe countries have looked into ERS practice and recommended best practices that the hydrographic surveying community use in ERS work as described in FIG publication No. 62. According to the authors' knowledge, besides Australia, several countries in East Asia region such as Japan, China, South Korea (Lee et al., 2017), Taiwan (Lin, 2016), Indonesia (Poerbandono, 2019) including Malaysia (Hamden et al., 2018) are intensifying the studies towards practicing ERS technique in the field of hydrography. For instance, Lee et al. (2017) had done research on ERS concept by analysing the feasible accuracy assessment of GNSS-derived height from carrier phase-based positioning. Two techniques were employed (Precise Point Positioning, PPP and Post Processed Kinematic, PPK), which infers that PPP-derived vertical solutions are more robust than PPK. This is because the comparison in Lee et al. (2017) was between PPP and medium range PPK in which the length of baselines was within the range 150 km to 260 km. These baseline lengths are far greater than the usual acceptable for single baseline PPK since single baseline PPK method is highly dependent on the distance between rover and its reference station. Thus, PPK is typically considered to be more robust than PPP for baselines length within approximately 20 km to 30 km depending on the weather conditions. In addition, Lin (2016) found that the ellipsoidal related bathymetric survey can prevent interference from various tidal zones and it is expected to replace the traditional bathymetry survey with ellipsoidally reference bathymetric survey in the future. Ligteringen et al. (2013) reported in their work that vertically, the height solution was less reliable than the horizontal solution, but that it was reasonably accurate to achieve the consistency of the tidal reduction solutions and to conform with the IHO S-44 standard.

3. Malaysia towards Implementing ERS

Malaysia is not left behind in attempting to realise ERS technique. Malaysia is essentially a maritime country, spanning approximately 4,700 kilometres of coastline and bordering on four main water bodies, namely Malacca Straits, South China Sea, Sulu Sea and Celebes Sea. The implementation of ERS project in Malaysia corresponds with its strategic location where most of the land area is surrounded by the sea. Furthermore, Malaysia is among the busiest maritime countries in terms of sea trade activities, especially in the Malacca Straits and South China Sea. Planning on implementing ERS technique as well as developing national seamless vertical separation model in Malaysia should be supported by several important agencies. Three main agencies involved in implementing and supporting ERS technique are academic institutions, Department of Survey and Mapping Malaysia (DSMM) and National Hydrographic Centre (NHC).

3.1 Role of Academic Institution

Universiti Teknologi Malaysia (UTM) is one of the academic institutions conducting on-going research in developing seamless vertical separation model (VSEP) for bathymetry derivation using ellipsoidally referenced surveying technique. This research is the first initiative in which the main idea is to realise ERS-derived bathymetry technique in Malaysia. VSEP model will be developed by modelling the assimilation of multi-mission satellite altimetry and tidal data to produce a series of stable reference surfaces. Bathymetry can be derived by integrating the seamless VSEP model with high-accuracy ellipsoidal height from GNSS data. Therefore, bathymetry referenced to the ellipsoid can subsequently be transformed to any derived surfaces. Vertical surfaces that needed to be included in VSEP model are:

i. Geoid model (MyGeoid), used to demonstrate the variation of the geoid with respect to the ellipsoid.

ii. Mean Sea Surface (MSS) produced from an average of multi-mission satellite altimetry derived sea surface height (SSH) over a period of time which covers the offshore area. Meanwhile, Mean Sea Level (MSL) produced an average level of the surfaces over 18.6 years at selected tide gauge stations that covers nearshore area.

iii. Mean Dynamic Topography (MDT) used to connect MSL or MSS to the geoid model.

iv. Lowest astronomical tide (LAT) and highest astronomical tide (HAT) produced from tidal datum modelling at selected tide gauge stations and satellite altimetry tracks.

GNSS derived bathymetry will be deployed at the study area when the VSEP model is well developed. The equations of depth determination as explained by Hamden and Din (2018) are still being adopted continuously in this research project. ***Figure 5*** depicts the pictorial representation on the migration of hydrographic surveying technique from the current practice towards implementing the ERS technique. To this end, if the research project is successfully developed, the academic institution such UTM can play a role to inculcate and provide awareness to the local practitioner in hydrography community to adopt this technique in hydrographic survey practice.

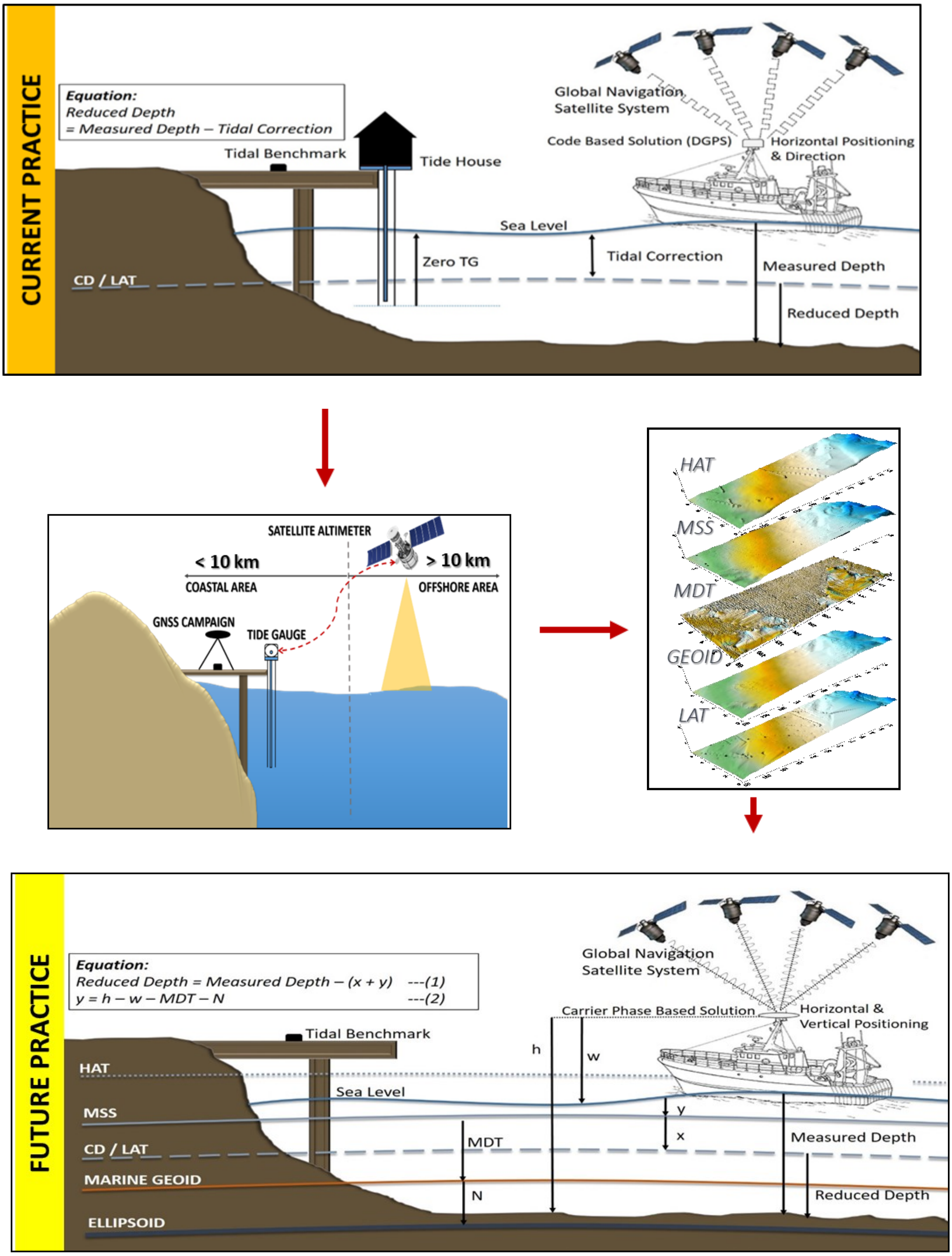

Figure 5 *Migration of hydrographic surveying technique from current practice towards implementing the ERS technique*

3.2 Role of Department of Survey and Mapping Malaysia (DSMM)

The Department of Survey and Mapping Malaysia (DSMM) is the most important agency in supporting the realisation of ERS technique. DSMM is the competent Malaysian Government authority in maintaining the National Spatial Reference System. This is achieved by the establishment of geodetic infrastructures including horizontal and vertical survey controls throughout the country for the purpose of national development, security and defence. DSMM has been developing geodetic infrastructures which indirectly would support the implementation of the ERS technique for future practice. The geodetic infrastructures are, namely, Continuously Operating Reference Station (CORS), also known as Malaysian Real Time Kinematic Network (MyRTKnet), Marine Geodetic Infrastructure (MAGIC) project and Tidal Observation Network.

i. Malaysian Real-Time Kinematic Network (MyRTKnet)

MyRTKnet is an infrastructure that has been formed by the GNSS network reference stations and control centre. It is also one of telecommunication systems which provide the GNSS data in order to deliver the position in real time. MyRTKnet service, which was established in 2003, consists of only 27 GNSS reference stations throughout the country. In an attempt to provide improved service to the users, the DSMM has now developed a total of 96 GNSS reference stations, of which 65 stations are located in Peninsular Malaysia and 31 stations in Sabah and Sarawak. Most of the stations are established at 30 km to 100 km intervals. The reference stations track and transmit GNSS signal through dedicated data lines to the control centre server at DSMM Geodesy section. Here, it manages and distributes the GNSS correction to the users in real time. Currently, all users will achieve centimetre precision. The distributions of MyRTKnet stations as shown in ***Figure 6*** can be retrieved in the website (http://www.rtknet3.gov.my/).

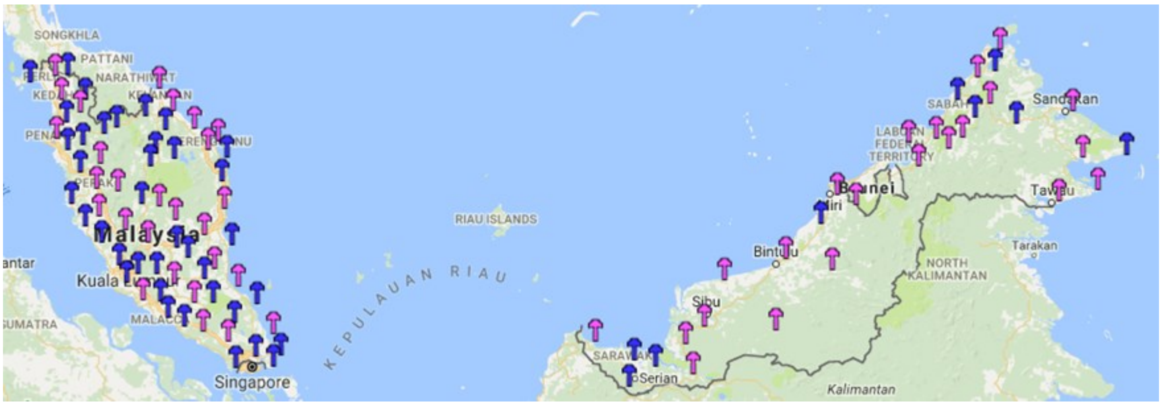

Figure 6 *Distribution of MyRTKnet stations in Malaysia (DSMM, 2018)*

Generally, the services provided by MyRTKnet are in form of data supply as shown in **Table 1.** The data supplied to the user consists of either real time data or post-processed data depends on the objective of the measurement itself. In the meantime, users need to comply with current measurement specifications conduct work to obtain good measurement results.

Table 1 Types of data provided by the Control Center (DSMM, 2005)

No.	Type of Data	Data Characteristics	Description
1	Virtual Reference Station (VRS) Correction	Real Time	• An integrated system which links and utilizes data from permanent reference stations to model errors throughout the coverage area. • This model is used to synthesize virtual reference stations near the user's location which then provide a localized set of standard format correction messages to the roving receiver.
2	Single Base Correction	Real Time	• Correction is provided for areas within 30 km from any MyRTKnet single permanent reference station. • Required through cellular phone connection and the corresponding differential data will be transmitted from the control centre to the rover.
3	Network Base Differential Global Positioning System (DGPS) Correction	Real Time	• Correction is provided for the whole of Peninsular Malaysia and areas within 150 km radius from Kota Kinabalu and Kuching. • This could be utilized in applications such as sub-meter mapping and navigation. Data availability upon request.
4	Virtual RINEX Data	Post Processed	• Virtual RINEX data are GNSS RINEX format data generated by MyRTKnet system based on approximate coordinates provided by users. • These data are the virtual reference station data that will be used as a reference by users for baseline computation.
5	RINEX Data	Post Processed	• The observed permanent reference station data in RINEX format are available through the website. • Data can be obtained at any interval ranging from 1s to 60s for post processing application.

This MyRTKnet provides reference station information for RTK or Post Processed Kinematic (PPK) technique during deployment of GNSS observation in ERS technique. The network RTK solutions are only applicable on the land areas due to the dense distribution of continuously operating reference stations (CORS). It is undeniable that a virtual base station solution established from network RTK allows much greater distances between base stations than single baseline solutions. Nevertheless, the deployment of

GNSS observation in ERS technique are focussing in the coastal and open seas. It is impossible to implement network RTK solution since the GNSS positions on the particular area are located outside of the network boundary. Therefore, for ERS applications, MyRTKnet system in regard to the single baseline solution is considered for coastal regions which baselines length restricted to 10-30 km. Beyond the coastal (open seas), PPP solution is considered since it is more robust than PPK technique as aforementioned.

ii. Marine Geodetic Infrastructure (MAGIC)

The MAGIC project intends to establish and maintain modern marine geodetic infrastructures for Malaysian waters with the primary objective to protect national sovereignty over marine area under its jurisdiction. Other objectives of this project are to strengthen geodetic ties in Malaysia waters development, scientific research and control of water security purposes as well as to enhance the nation's geodetic and geospatial data supply (Azhari et al., 2017). There are five project components of MAGIC, which are as follows:

a. Marine Geodetic Network (MGN) of Islands near the international maritime boundary. Establishing MGN is to connect the land and marine areas under the Geocentric Datum of Malaysia 2000 (GDM2000).

b. Establishment and upgrading of Permanent Active Marine Geodetic GNSS Stations with the primary purpose of strengthening the existing GDM2000 in the marine areas.

c. Marine Geodetic Height System over Malaysian waters which is to provide seamless spatial data across land and sea interface. This is because Malaysia does not have a consistent vertical datum across land and sea interface.

d. Seabed Topography Survey for Malaysian waters with the main objective of creating a continuous land to sea large scale base map to support DSMM's marine cadastre project.

e. Upgrading a Central Processing and Database Centre for the Marine Geodetic Infrastructure. Marine Geodetic Database (MGDB) has been established using ArcGIS Database System. This MGDB will act as a base for the implementation of a robust Marine Spatial Information Infrastructure (Marine SDI) for Malaysia.

iii. Tidal Observation Network

The key purpose in installing tide gauge stations is to determine a continuous time series of sea level for the purpose of establishing a vertical datum for the nation. DSMM is one of the few organisations responsible for the general management of data collection, validation, analysis and dissemination of sea level data. ***Figure 7*** shows the distribution of DSMM tide gauge stations in Malaysia.

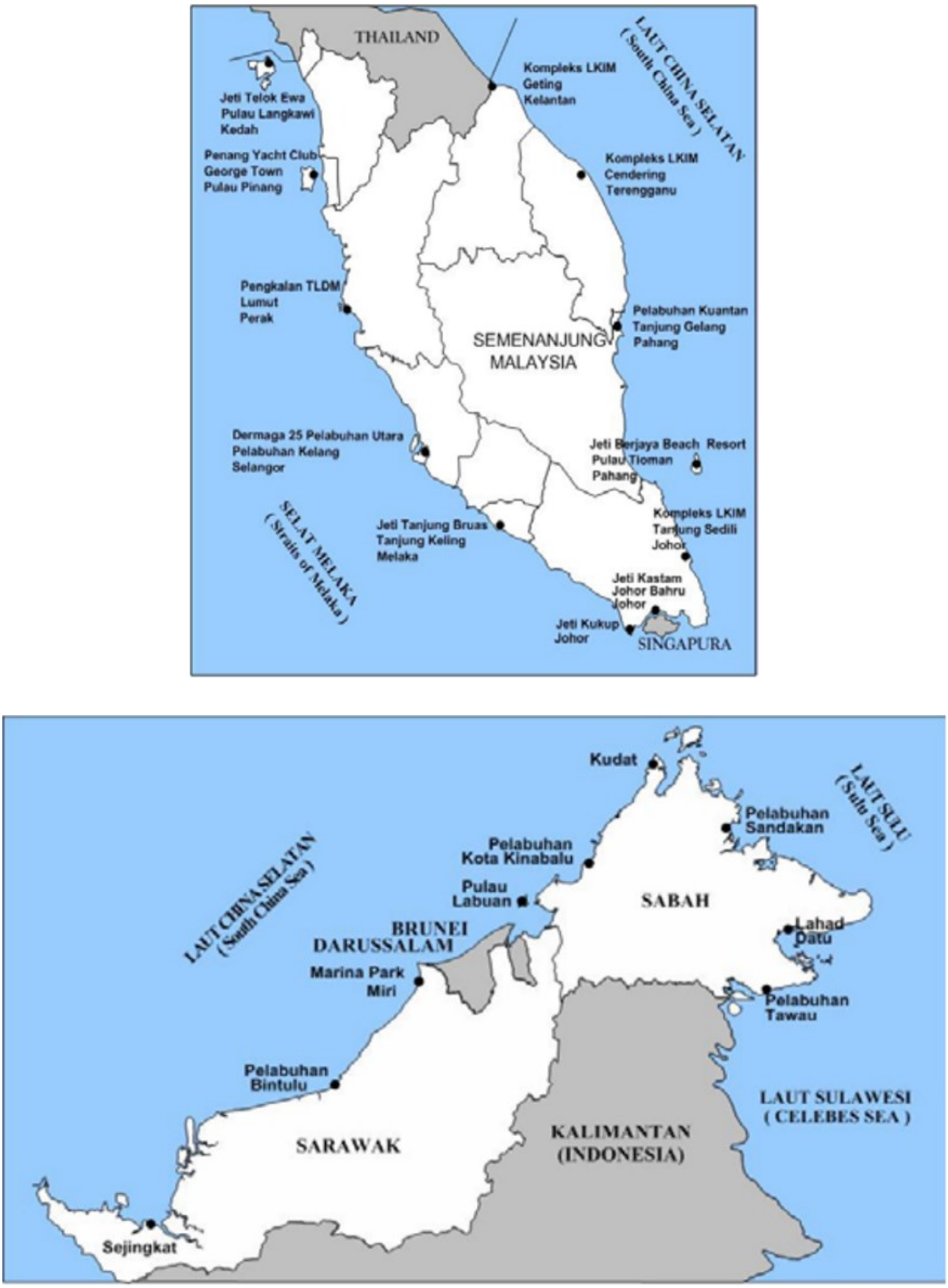

Figure 7 *Distribution of DSMM tide gauge stations (DSMM, 2012)*

DSMM handles the Tidal Observation Network (TON) of 21 continuously operating tide gauge stations along the coast of Malaysia. Nevertheless, two stations have ceased operation, which are Johor Bahru in 2014 and Sejingkat in 2010. DSMM also took an initiative to connect some of the tide gauge stations in the national TON with telemetry connections such that the data of sea level can be transmitted automatically to the central facility in Kuala Lumpur. To this end, the tidal data from tide gauges are important in developing VSEP model as this data will be utilised to derive various vertical datum such as MSL, LAT, HAT and MDT that represents nearshore areas.

3.3 Role of National Hydrographic Centre (NHC)

Apart from DSMM, the National Hydrographic Centre (NHC) is also one of the agencies that can be considered important in realising ERS technique in Malaysia. This is because NHC is responsible for carrying out the regional hydrographic survey of Malaysia. The NHC is an agency that represents the government in addressing more global issues such as technical issues of maritime demarcation. In relation to the research project, the academic institution could collaborate with NHC in terms of testing the reliability of the developed VSEP model during deployment of ERS technique. Since NHC produced nautical charts for Malaysia, comparison between ERS-derived bathymetry and the depth from nautical chart can be analysed.

4. Conclusion

This paper has summarised and reviewed the nations that have successfully implemented ERS technique in which developing and validating the vertical separation model are the greatest challenge. A number of organisations have developed or are in the process of developing vertical separation model. Their projects have been commenced either for hydrographic purposes in permitting the utilisation of GNSS for referencing depth measurements or to empower the creation of seamless coastal datasets. Thus, the vertical datum transformation projects that have been conducted, such as VORF by UKHO, VDatum by NOAA, AusCoastVDT and AUSHYDROID by Australia, for example, can be used as a handbook or reference sources in implementing ERS technique in Malaysia. As Malaysia is looking forward to implement this technique, a proper guideline as well as work process must be designed in detail. As such, there is a need for coordination, support and participation among the various government agencies or stakeholders affected, for instance, DSMM and NHC including academic institutions in realising ERS technique for hydrography survey practice in Malaysia. In the event that this ERS practice is favourable or acceptable, it could become a game changer towards the current practice of hydrographic surveying. This would also be a new norm for the hydrographic community especially for Malaysian Hydrographic Society (MyHS) in carrying out their hydrographic works in the future.

5. References

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