MODELLING THE TIDAL DATUM VARIABILITY AT THE STRAIT OF MALACCA

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Abstract

Strait of Malacca is considered as one of the busiest straits in the world. It is approximately 1,000 km long, 300 km wide at the north-west entrance, and 12 km wide at the south-east entrance between Singapore and Indonesia's Riau Archipelago. The bathymetry in the area is shallow with narrow channels and shifting bottom topography, hence having irregular tides over the region. The tidal streams entering from each ends of the strait meet near Port Klang, causing the large tidal range over 4m near the port, while at the entrances it's just 1 to 2m. The measured water levels obtained at a tidal station are analysed of a long period and the tidal datums are established. International Hydrographic organisation (IHO) recommends the Lowest Astronomical Tides (LAT) for reduction of soundings in the navigational charts. However, different countries and agencies adopt different other datums like Mean Lower Low Water (MLLW), Indian Spring Low Water (ISLW), Mean Sea Level (MSL), etc depending on their purpose. To establish proper datum values, one must observe water levels continuously over 18.6 years to account for full tidal nodes. Tidal factors may alter rapidly over an area especially with the local conditions. IHO standard for the datum variability is, it should not exceed 0.1m from the actual. Therefore, it is important to know how the tidal datum fields are distributed over an area. However, most of the tidal networks are sparse, hence inadequate due to the complexity of the tidal character. Because of these reasons, proper datum levels are not known at most of the locations. Furthermore, most of the common interpolation techniques are less effective in applying to tides. Therefore, in this paper, spatial interpolation techniques were used to model the spatial variability of different tidal datums in the Strait of Malacca. The results are compared against several secondary ports datum levels and proven that this is an effective and faster approach even though it does not account any tidal physics. These results can be use as the preliminary information about the tidal datum distribution over the region and can also assists the maritime boundary delineation process.

Keywords: *Tides, Spatial Variability, Hydrography, Tidal Datum, Numerical Modelling*

1.0 Introduction

Tidal datums are height levels obtained at the tidal stations by analysis of a long period of water level observations. International Hydrographic organisation (IHO) recommends the Lowest Astronomical Tides (LAT) for reduction of soundings in the navigational charts. However, different countries and agencies adopt different other water level datums like Mean Lower Low Water (MLLW), Mean Sea Level (MSL), Indian Spring Low Water (ISLW), etc depending on their purpose. To establish proper datum values, one must observe the water levels continuously over 18.6 years to account for full tidal nodes. These factors may alter rapidly over an area especially with the local conditions (Hicks, 2006). Therefore, countries have established tidal networks mainly along the coastal belt to measure and analyse the tidal phenomenon. However, most of these networks are inadequate or sparse due to the complex tidal character. Because of these reasons, proper datum levels are not known at most of the regions. Most of the common interpolation techniques are inappropriate or less effective in applying to tides (Hess *et. al*, 2004), whereas the hydrodynamic models are more complicated and require extensive data processing and time for calibrating (Turner *et. al*, 2010). Spatial interpolation techniques have shown effective results and being widely used in many fields of sciences like environmental sciences and metrological parametric modelling (Daley, 1993). However, appropriate boundary conditions must be determined in the first place.

2.0 Methods

Strait of Malacca is bounded by North-East coast of the Indonesian Sumatra Island and South-West of the Peninsular. Most of the area is shallow waters with complex coastlines. Two tidal streams enter the strait, one from the northeast and the other from the southwest and mix together at the centre somewhere near Port Kelang, causing the largest tidal range around there. Since it is a busy navigation channel, lots of historical and current tidal stations were found. For this study, all together 20 tide gauges (historical & running) were chosen over the both edge of the strait.

Here, the tidal datum fields are assumed to be obeying the two Dimensional (2D) Laplace's Equation (LE) and the datum interpolation is computed by numerically solving the LE on a gridded mesh. The boundary conditions were determined for the water-land and open water boundaries. The datum levels at the selected stations were used as the known values. A 10km cell size was chosen and totally 64x82 cells were needed to cover the area. Ten stations were used as the known stations. Successive Relaxation (SR) technique was used to speed up the computation process.

A Matlab coding was developed to perform the computation and the results were converged after little over 1700 iterations just under 96 seconds. For each datum, datum levels at the unknown cells are computed separately in similar manner. The remaining ten tidal stations were used to check the results computed and validate the proposed method. Here, all the datum levels are referenced to the MSL.

3.0 Results & Conclusion

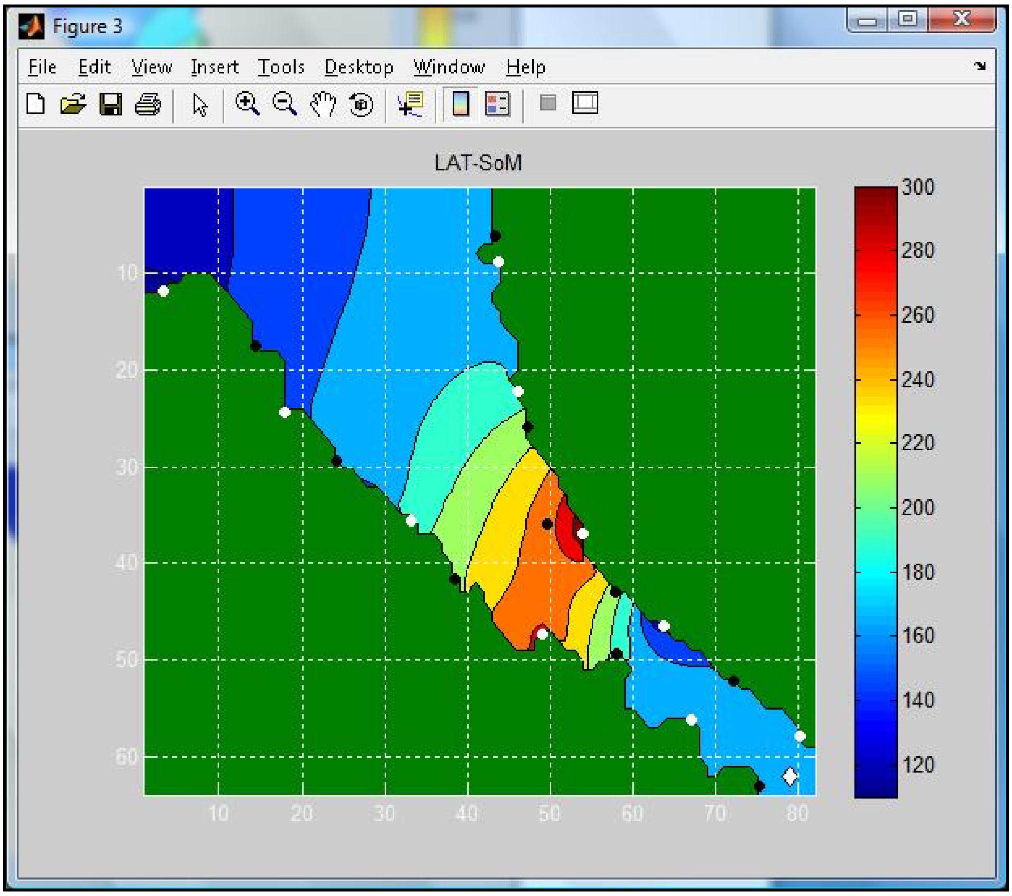

Figure1**:** Spatial variability of the LAT in the Malacca Strait (values below MSL). White dots represent the tidal stations used in the modelling and the black dots are the check stations.

Table 1: LAT and ISLW Datum Comparison.

Tidal Station	Difference in LAT (m)	Difference in ISLW (m)
LangsaBay	-0.01	-0.03
Kualatanjung	-0.02	0.01
Bagan	-0.04	-0.02
Tj Medang	0.07	0.02
Blandong	0.21	0.28
Pulau Pisang	0.08	0.05
Batu Pahat	-0.05	-0.07
Port Dickson	-0.05	-0.06
One Fathom Bank	0.04	0.05
Bagan Dato	-0.08	-0.06
Tj Dewai	-0.07	-0.05

Strait of Malacca is a tidally complex area. Even though, the tidal pattern is dominantly semi diurnal, the range shows a great differences. Here, LAT on the northeast Sumatra coastline vary from -1.1m at Lhokseumawe to -2.7m at Tanjung Senaboi and -1.8m at Tanjung Parit. At the southwest coast of Peninsular Malaysia, it varies from -1.7m at Pinang to -3.0m at Port Kelang and -1.9 at Kukup. The ISLW ranges from -1m at Lhokseumawe to -2.7m at Tanjung Senaboi and -1.5m at Tanjung Parit. Same time, it varies from -1.2m at Pinang to -2.3m at Port Kelang and -1.9m at Kukup on the southwest coast of Peninsular Malaysia. The computed datum levels match clearly with the referenced intermediate secondary ports datum values and agreed with the IHO standards (<0.1m) except at the Blandong station. This may due to the insufficient tidal data observed, hence it influenced to the derived datum level determination.

It is clear that the use of numerical solution of 2D LE in modelling the tidal datum fields is an effective and faster approach, even though it does not require any tidal factors such as tidal constituents, hydrodynamics, bathymetry, etc. This result can be used as preliminary information in determining the best location for the new tidal stations for the future hydrographic surveys and further densification of the existing tidal network. This can also assists the maritime boundary demarcation process in marine database development.

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