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Evaluation of Coastal Model Performance using Statistical Analysis at the Kelantan Coast, Malaysia

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Abstract

Coastal zones are vulnerable to the effects of nature and man, as well as being physically volatile. The interaction of hydrodynamic conditions in coastal areas is a complex phenomenon. Considering the characteristics in this specific area, understanding its hydrodynamic behaviour should be obviously clarified. Thus, the hydrodynamic characteristics at Kelantan coastal had been simulated using a numerical model of MIKE 21 Hydrodynamic FM. To assess the performance of the model, a combination of time series analysis and statistical evaluation were done against observed data such in two weeks of the period. Time series analysis showing a good agreement and corresponding magnitude and phase with the field measurements. Statistical analysis using Root Mean Squared Errors (RMSE) and Regression analysis (R^2) were analysed with RMSE for current speed are 8.97% and 8.00% for ADCP 1 and ADCP 2 respectively and for water level is 8.89 %. Through the regression analysis, the output indicates that the numerical model is in a good performance as the R2 ranged from 0.72 to 0.9. Both time series and statistical approach was successfully utilised in the hydrodynamic model to determine the performance of the coastal hydrodynamic caharacteristics in Kelantan's coastline and the output model at the

Kelantan coast can help and provide important information, especially management and land-use planning for the developers, planners and state authority.

Keywords: Hydrodynamic, RMSE, Regression analysis, Numerical Modelling, Coastal

Introduction

The Coastal zone is one of the most important areas for human activities and infrastructure development (Kulkarni, 2013). However, this system is dynamic and essential to be studied widely before infrastructures are planned to avoid any damages caused by natural processes such as erosion. The main natural elements responsible for coastal hydrodynamics are bathymetric, waves, wind, currents and tides (Fitri et al., 2017; Department of Irrigation and Drainage, 2001) . This information is very significant for various coastal engineering applications especially on coastal protection structures. Furthermore, monitoring and understanding the hydraulic study and hydrodynamic characteristics are significant issues for coastal engineering-related activities. Thus, physical and numerical modelling are important tools for researchers to mimic and solve the problem of coastal processes for many years.

Physical models are rescaled model into a smaller size to represent actual dominant forces in the correct proportion system. While, numerical models using a mathematical formulation that has been described as hydrodynamic processes to represent coastal processes well (Blacka et al., 2007). However, the performance of the coastal models needs to calibrate and verify with sufficient observed data because of the complex elements in the coastal area (De Vos et al., 2021; Prasetyo et al., 2018). Several numerical models have been demonstrated to identify the best approach for understanding hydrodynamics characteristics due to dynamic environment in coastal area and these models are recently being used as effective tool to help in decision making by using predictive software such as MIKE 21. DHI known as a Denmark Hydraulic Institute, (2011) is a commonly produced a comprehensive modelling module from MIKE 21. The modules in MIKE 21 had shown in various applications such as design assessment, optimisation of coastal structures, environmental and ecological assessment in the coastal dynamics

The human population and activities are increasing in the coastal regions. Therefore, numerical modelling is effective tools in order to ensure that the coastal areas do not become hazardous to human life and economic interests, the places are safe and sustainable (Ariffin et al. 2020; Ehsan et al. 2019; Gill et al., 2014; Helmy, 2018; Rashidi et al. 2021). It is crucial to understand the hydrodynamics and the transport of sediments on coastal areas and their effects (Haditiar et al. 2019; Tam et al. 2019; Zhang et al., 2009). Coastal hydrodynamics and transportation of sediment using numerical modeling is an ordinary way for assessing problems with Coastal Engineering (Sawczyński & Kaczmarek, (2014). Nevertheless, many numerical modelling techniques for coastal areas are being created, but not very much research on the Kelantan Coast particularly on hydrodynamic model performance has been done.

Therefore, the main objective of this research is to test and assess the accuracy and performance of the simulation of hydrodynamic processes at the Kelantan coastline by using unstructured hydrodynamic approach of the software MIKE 21 FM model (Denmark Hydraulic Institute, 2011).

Literature review

The coastal processes on the east coast of Peninsular Malaysia are influenced by the monsoonal system brought from East Asia, which during the winter season delivers a high intensity of linked physical natural phenomena associated with current speeds, tides, waves, winds, and rainfall frequency has a significant impact on the cycle of beach erosion and accretion in Malaysia. Peninsular Malaysia has a coastline length of 1,972 kilometres out of a total length of 4,809 kilometres (Ehsan et al. 2019; Fazly Amri Mohd et al. 2018; Gill et al., 2014; Razak et al. 2018). More than half of the Peninsular coast's east and west coasts are eroding.

Recent coastal development and land use change have required the creation of comprehensive numerical modelling software to calculate coastal erosion, the impact of engineering works, and the influence on the ecological environment (Gill et al., 2014; P et al. 2019; Rashidi et al. 2021; Razak et al. 2018; Tam et al. 2019; Tobergte and Curtis 2013). Because of the considerable diversity in physical forcing, geometry, hydrodynamics, and circulation of estuarine systems, a variety of numerical models have been developed, each designed for a specific purpose.

Time series and statistical output often used to assess the model's simulation performance with data measurement, time series analysis is greatly helps in the calibration step however, this is not informative enough to minimise the discrepancies in the model hence statistical analysis are recommended to quantify the goodness of fit (Williams and Esteves 2017; Mirzaei et al., 2013; Chu et al., 2004). The model's accuracy can be calculated using root mean square error (RMSE), which is the average squared difference between the measured and predicted values. The RMSE values indicate the less residual value between both two data denote better model performance (Simon et al., 2018). However, RMSE analysis has greatly emphasized large errors than small ones and it also sensitive with false or outlier in the data set (Kavuncuoglu et al., 2018). Therefore, a regression model using the coefficient of determination or R-squared (R^2) is often used by represents the proportion of the variance in the dependent variable.

According to the previous study, there is a serious lack of knowledge about Kelantan Coastal that is related to historical records of physical marine data and hydrodynamic modelling studies. Regarding Mohtar et al., (2017), a numerical modelling study has been conducted using the MIKE21 model suites to evaluate the hydrodynamic parameters in the Kelantan Delta. The marine affects on the study region are intimately tied to the Monsoons, with the Northeast Monsoon having the highest sea and swell conditions (Effi Helmy Ariffin, et al., 2018; Ehsan et al. 2019; Helmy, 2018; Maruti et al., 2018; Samaras et al., 2013; Toriman et al., 2015). A lack of a comprehensive strategy to guide integrated and sustainable management, such as changes in land use that result in degradation and reduced size of the various wetlands habitats, will consequently disrupt the economic value for the local population.

Another research conducted by Azad et al., (2016) mentioned that flood propagation could be better understood by employing hydrodynamic modelling to simulate velocity and water level. The spatial complexity of the schematization, such as 1D model and 2D model, can be used to identify hydrodynamic flood routing. Therefore, a flood mitigation strategy can be designed using hydrodynamic modelling for future flood protection.

Material and Methods

MIKE 21 Flow Model FM is based on two dimensional modelling system that uses a unstructured mesh approach. This model relies on the flexible mesh method and it is generally used for most coastal and marine approaches (Jusoh et al., 2014; Borgersen, 2016). The Hydrodynamic module is one of the basic computational components of the entire MIKE 21 Flow Model modelling system (Denmark Hydraulic Institute, 2011). This module simulates various environmental application over geographic areas in lakes, river mouths, lagoons, bays, shallow water areas, and open seas. The flows of hydrodynamic in the coastal areas are calculated in x and y direction based on volume and momentum as shown on equations following:

Y-direction;

$$\frac{\partial p}{\delta t}+\frac{\partial}{\delta y}\left(\frac{p^2}{h}\right)+\frac{\partial}{\delta x}\left(\frac{pq}{h}\right)+gh\frac{\delta \xi}{\delta y}+\frac{gp\sqrt{p^2+q^2}}{C^2.h^2}-\frac{1}{p_\omega}\left[\frac{\delta}{\delta x}(h\tau_{yy})+\frac{\delta}{\delta x}(h\tau_{xy})\right]-\Omega_q-fVV_y+\frac{h}{p_\omega}\frac{\partial}{\delta y}(p_a)=0,$$

X- direction;

$$\frac{\partial p}{\delta t}+\frac{\partial}{\delta x}\left(\frac{p^2}{h}\right)+\frac{\partial}{\delta y}\left(\frac{pq}{h}\right)+gh\frac{\delta \xi}{\delta x}+\frac{gp\sqrt{p^2+q^2}}{C^2.h^2}-\frac{1}{p_\omega}\left[\frac{\delta}{\delta x}(h\tau_{xx})+\frac{\delta}{\delta y}(h\tau_{xy})\right]-\Omega_q-fVV_x+\frac{h}{p_\omega}\frac{\partial}{\delta x}(p_a)=0,$$

The equation of continuity:

$$\frac{\partial \xi}{\delta t}+\frac{\delta \rho}{\delta x}+\frac{\delta q}{\delta y}=\frac{\delta d}{\delta t}$$

Where x and y are direction components, (x,y,t) is surface elevation (m), h(x,y,t) is water depth (m), d is time variable water depth (m), g is gravity acceleration (m/s2), atmospheric pressure (kg/m/s2), p_ω is the water density (kg/m3), and τ is shear stress.

Data required for the hydrodynamic flow model from MIKE 21 consists of bathymetry data from the computational domain, river discharge from the main connected river, meteorological parameters, sediment properties and bed resistance. Figure 1 depicted a location of the study area and situated facing the South China Sea which the tidal dynamic and circulation of current pattern in this area are mostly influenced by the geographical, topographical and monsoon winds which agreed by many previous studies (Wyrtki, 1961; Chu et al., 2004; Zu et al., 2008; Han et al., 2021).

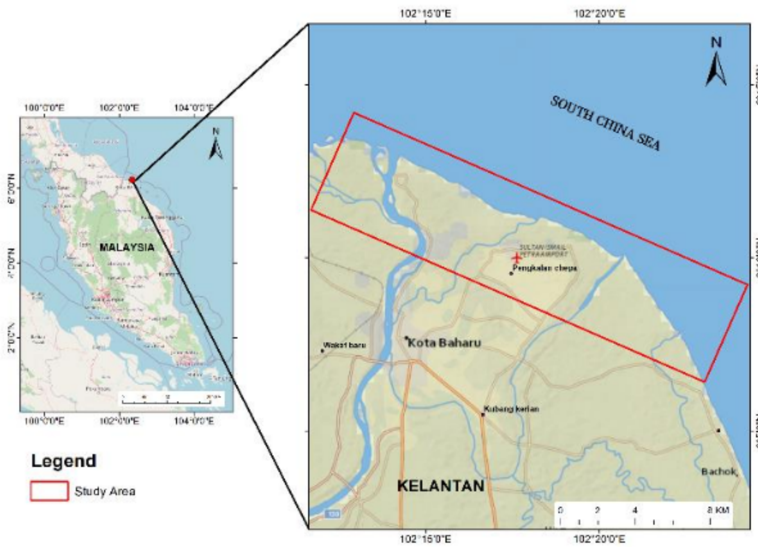


Figure 1. Study location at coastal area of Kelantan

A high-resolution bathymetry study was carried out along the Kelantan coast, covering an area from Sungai Kemasin to Sungai Kelantan which is approximately about 20 km x 5 km as shown on Figure 2. This survey was done during the spring tide in July 2018. The data observation recorded includes depth from -0.01m to -11.54m relative to a chart datum. Furthermore, the bathymetry data for the ocean region was extracted using C-MAP digital chart which has been included in the DHI package. The bathymetric map was handled by MIKE Zero's Bathymetry Editor and Mesh Generator (Denmark Hydraulic Institute, 2017) to produce a flexible mesh with spatial grid resolution ranging from 10 m along the shoreline to 3,000 m towards the open sea.

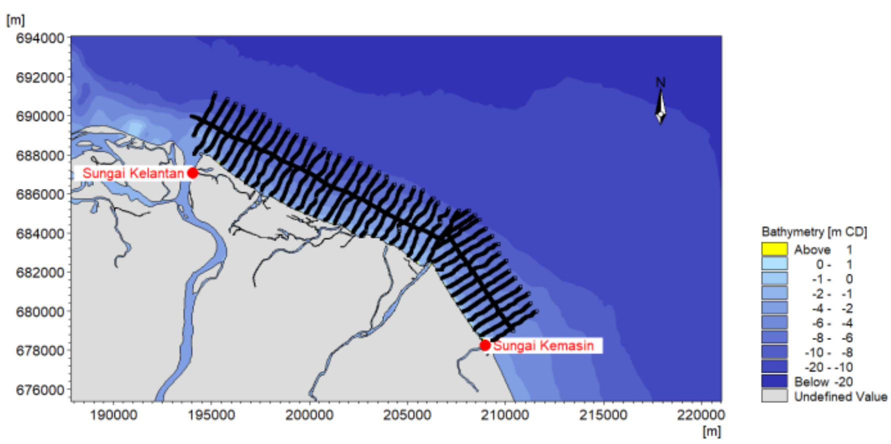


Figure 2. Conducted bathymetry survey along Kelantan Coast

At the boundary condition in Kelantan model, the computational domain is enclosed by the four boundaries consists of shoreline, an offshore boundary, and two open cross-sections in the lateral boundary (Ding et al, 2016). This task's goal is to allow water level energy as primary forcing across the model domain. Following that, the boundary information for each code is specified. A code value for open water boundaries can be provided when the mesh was built using the MIKE Zero Mesh Generator. An offshore boundary for code 3(East) and lateral boundary for code 2 (South) and code 4 (North) are specified in the mesh file. Water levels generated are obtained fromglobal tide model provided by DHI.

As illustrated in Figure 3, two units of Acoustic Doppler Current Profiler (ADCP) were erected at two places along the Kelantan's coast, which identified the South China Sea shoreline and covered complete semidiurnal tidal periods. The ADCP were used to measure vertical current profile data to produce current speed and its directions which later to be used in calibration and verification process. The water level data at Kuala Besar Marine Department's Jetty was installed and recorded with a Tide Gauge at 10-minute intervals. All the measured data have been collected for 14 days from 27th to 9th August 2018 in the study area.

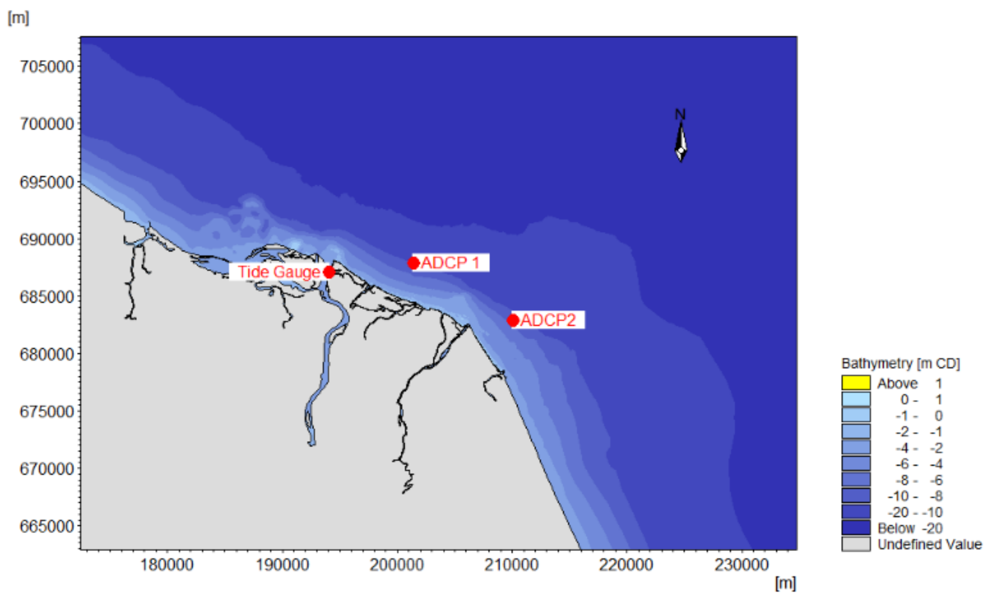


Figure 3. The Locations of ADCP 1 and ADCP 2 at Kelantan Coastal

Results and Discussions

Time Series Analysis

The water level, current speed, and its direction are all measured in real time (in-situ) at the northeast part of Peninsular Malaysia were collected and validated with model simulation. Figure 4 shows the pattern of water levels obtained from simulations for the jetty of Kuala Besar Marine Department has a good agreement and corresponding shape with the field measurements. The finding is consistent with findings of past studies by Azid et al., (2015), which found that the flow patterns around this study area correspond to the impacts of the semidiurnal tides, which have two high tides and two low tides on a lunar day. In 2008, Zu et al.,(2008) found that the response of tidal dynamics in the South China Sea are greatly influenced by local geometry and bottom topography.

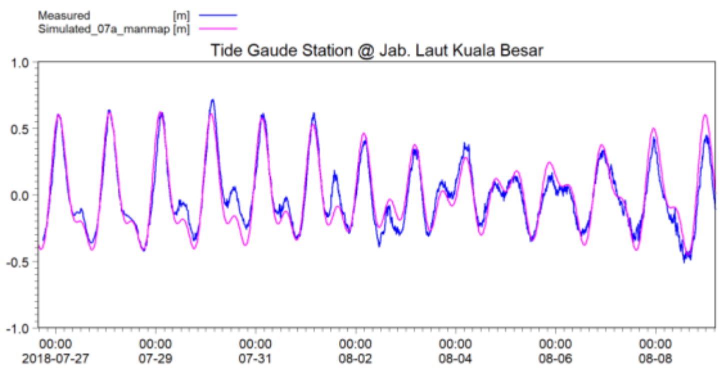


Figure 4. The pattern of water level at Jetty of Jabatan Laut Kuala Besar.

Figure 5 shows time series validation for current speed between simulation and field measurements at ADCP1 and ADCP2. The analysis showing a good result with current characteristics is greatly influenced by tidal amplitude, phase and direction especially during peak flow for ebb and flood tides (Williams and Esteves, 2017). A research finding by Mohammad Noor et al., (2013) also mentioned that Kelantan coastal is facing the South China Sea, and numerous anthropogenic activities such as human residences and recreational facilities have been constructed along the beach. Therefore, these activities would be affected the marine ecosystem nearby. In 2017, Kamarudin et al., (2017) demonstrated that the speed of water flows is the main factor, which affected the capacity to transport the sediment and the sediment movement. Furthermore, Radzir et al., (2018) stated during the northeast monsoon, the Kelantan River delta and coastal shoreline were impacted by a destructive wave that caused erosion at the higher beach and deposits at the offshore bars.

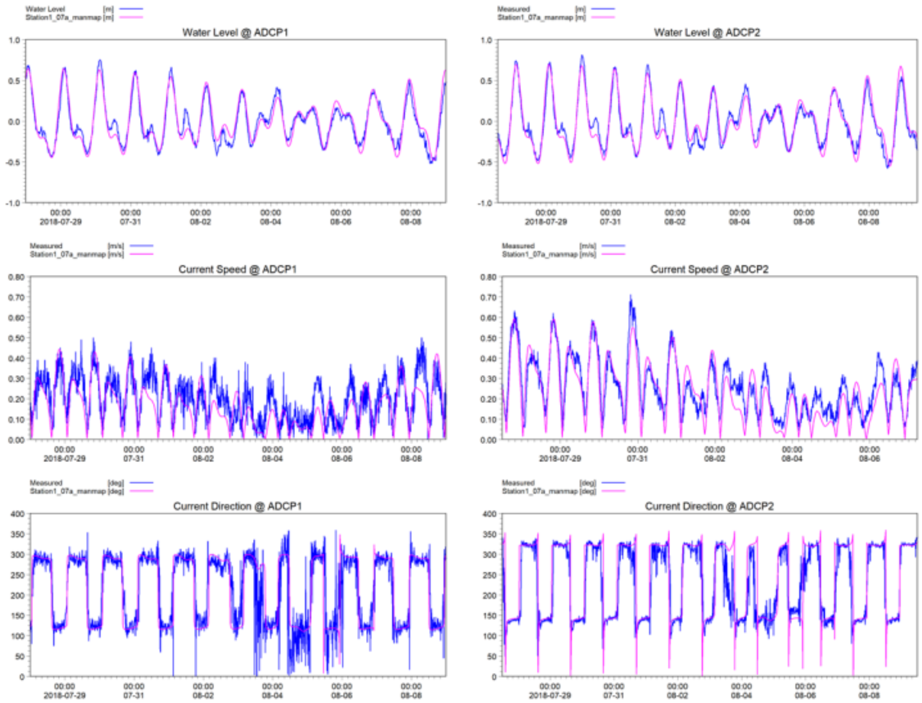


Figure 5. Time series comparison between observed and simulated data at station ADCP1 and ADCP2 for water level, current speed and current direction

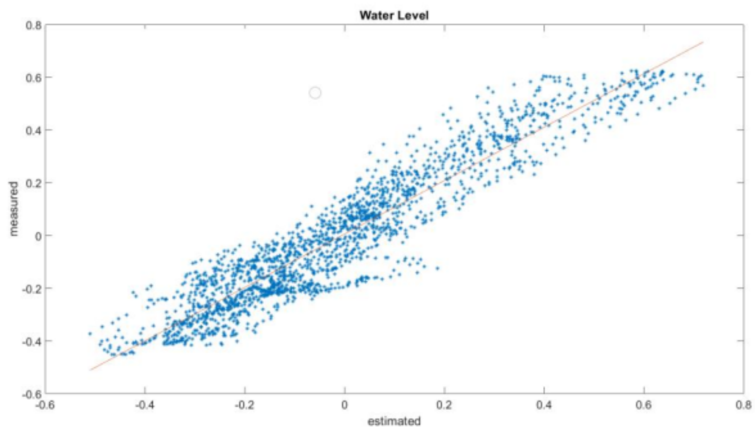
Root Mean Square Error (RMSE) and coefficient of determination (R^2)

Table 1 shows the values of Root Mean Square Error (RMSE) and coefficient of determination (R^2) in the model calibration and validation process. The RMSE values for calibration and validation of water level at three stations indicated good performance based on the 'Guidelines for Preparation of Coastal Engineering Hydraulic Study and Impact Evaluations, 5th Edition' published in December 2001 and a piece of additional information published in 2013. Regarding the Hydraulic guideline on the Department of Irrigation and Drainage (DID) on 2013, the standard error allowed for current speed should be no more than 20%. For the water level, the tolerance of DID requirement is not more than 10%. From the results, the RMSE value for all stations are comparable between current speed and water level with the value ranging from 8.0% to 8.89%. As this model is only forced by pure tide conditions, the resulting RMSE value is almost similar.

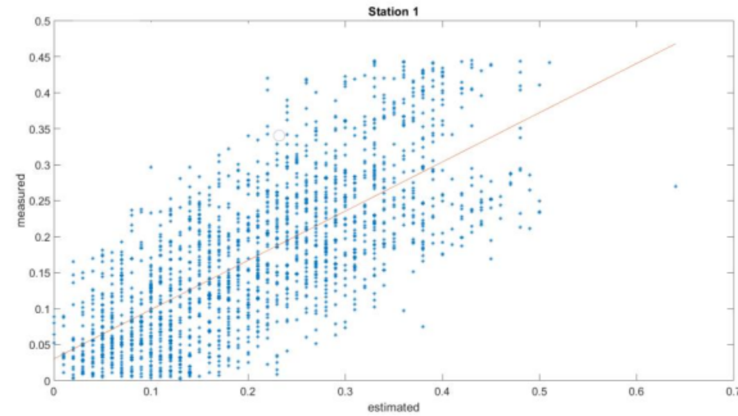
Table 1. Statistical Methods using Root Mean Square Error (RMSE) and coefficient of determination (R^2) for water level and current speed parameters

No	Hydrodynamic Parameters	RMSE (%)	R^2
1	Water Level (m)	8.89	0.94
2.	Current Speed (m/s)		
	ADCP 1	8.97	0.72
	ADCP 2	8.00	0.87

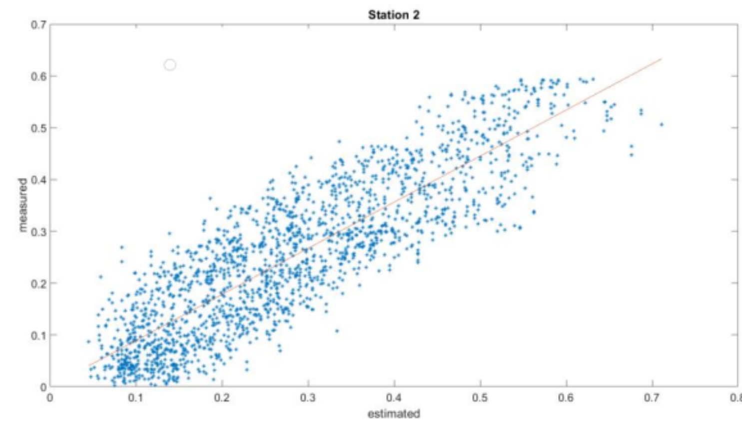
Based on the regression method, coefficient of determination (R^2) has been obtained to provide how good model performance as a predictor as shown in Figure 6. The result of water level and current speed for this research region is calculated to be exactly 1, showing that this simulation model provides a good prediction output. The results also produce a significance level of the correlation values with $p<0.05$ for all stations. The range of these hydrodynamic parameters is around 0.72 to 0.94. From the results, the R^2 values at ADCP2 found to have a high correlation value compared to ADCP1, this is might be due to high noise in the observed current speed on ADCP1 which resulting low R^2 value as shown in time series analysis. In the hydrodynamic parameter, high R^2 for water level compare to current speed is expected because the observed current speed is always much noisier than the water level. Hence, the water level parameter is shown better performance compared to the current speed.



(a) Water level at tide gauge station



(b) Current speed at ADCP1



(c) Current speed at ADCP2

Figure 6. Regression model and calculated coefficient of determination (R2) at measuring stations.

Furthermore, since the model is forced by purely tide conditions, it is expected to get a high correlation value because tide is predictable compared to current except under the influence of extreme meteorology factors such as storm surge (Polagye et al., 2010). In terms of magnitude deviation, other factors (e.g. meteorological, river discharge) may play an important factor in the RMSE value. Hence, the RMSE value is higher for water level compared to the current speed.

To achieve the most accurate predictions, both statistical methods were tested. As a result, almost of the statistical approaches used in this research showed that the model is well calibrated, validated and accepted. It is crucial to have an accurate model, especially along Kelantan coast where the hydrodynamic processes are complex and complicated. A study by Zu et al., (2008) stated that the veracity of the coastal topography is played an important role in order to determine model accuracy. Meteorological forcing such as wind and waves, dynamic morphology and complexity of coastal processes in this area may not be well resolved could be a reason current speed performance is lower than water level. In addition, higher model grid resolution and accuracy of bathymetry and topography survey are an important factor to improve the efficiency of the coastal modelling (Brown & Kraus, 2007; Reid et al., 2014). Plus, the study areas are prone to high risk during the heavy rainfall season from December to February. Wan Ahmad & Abdurrahman,(2015) reported on 2014, eight Kelantan territories are affected severely due to heavy rains that caused massive flooding. During these events, a natural disaster may cause major damages to the community and existing infrastructures. Therefore, during the monsoon season, implementing meteorology forcing may require to improve model performance in this study area.

Conclusions

The statistical approach applied in the numerical model for this research gave a high performance between the model simulation and the measured data. The RMSE and regression method had been effectively applied in the hydrodynamic model for recognizing the accuracy of the hydrodynamic parameters at Kelantan Coastal. The output indicates that the numerical model is in a good performance for the water level, current speed and current direction. Finally, the model output at the Kelantan coast validated and can help and provide important information, especially management and land-use planning for the developers, planners and state authority.

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References

Azid, A., Noraini, C., Hasnam, C., Juahir, H., Amran, M. A., Toriman, M. E., Kamarudin, A. (2015). Jurnal Teknologi Full paper Coastal Erosion Measurement Along Tanjung Lumpur to Cherok Paloh, Pahang During the Northeast Monsoon Season. Journal Teknologi, 1, 27–34.

Ariffin, Effi Helmy et al. 2020. "Evaluating the Effects of Beach Nourishment on Littoral Morphodynamics at Kuala Nerus, Terengganu (Malaysia)." *Journal of Sustainability Science and Management* 15(5): 29–42.

Azad, Wan Hazdy et al. 2016. "2 Dimensional Hydrodynamic Flood Routing Analysis on Flood Forecasting Modelling for Kelantan River Basin." *MATEC Web of Conferences* 87(January).1-7

Blacka, M., Carley, J. T., Cox, R. J. & Miller, B. (2007). The Current use of Physical and Numerical Models for Coastal Applications. University of New South Wales Coastal Conference, 2007.

Borgersen, B. T. (2016). Numerical Modelling of Arctic Coastal Hydrodynamics and Sediment Transport. Master Thesis, Norwegian University of Science and Technology.

Brown, M.E. and Kraus, N.C. (2007). Tips for Developing Bathymetry Grids for Coastal Modeling System Applications. Coastal and Hydraulics Laboratory Engineering Technical Note ERDC/CHL CHETN-IV-69. Vicksburg, Mississippi: U.S. Army Engineer Research and Development Center, 15p.

Chu, P.C., Qi, Y., Chen, Y. Mao, Q. & Shi, P. (2004). Journal of Atmospheric and Oceanic Technology. Vol. 21, pp. 1718-1733.

de Vos, M., Vichi, M. & Rautenbach, C. (2021) Simulating the Coastal Ocean Circulation Near the Cape Peninsula Using a Coupled Numerical Model. Journal of Marine Science and Engineering. Vol. 9(359). https://doi.org/10.3390/jmse9040359

Denmark Hydraulic Institute (DHI). (2011). MIKE 21 FLOW MODEL FM. User Guide. Danish Hydraulic Institute, 2011.

Denmark Hydraulic Institute (DHI). (2017). MIKE C-MAP. Danish Hydraulic Institute, 2017.

Department of Irrigation and Drainage. (2001). Guidelines for Preparation of Coastal Engineering Hydraulic Study and Impact Evaluation Malaysia, pp 1-30.

Ding, Y., Jia, Y., & Wang, S. S. Y. (2016). Numerical Modeling of Morphological Processes around Coastal Structures. In: Proceedings World Environmental and Water Resource Congress May 21-25 2006. Sponsored by the Environmental and Water Resources Institute of ASCE. 10-20. Omaha, Nebraska.

Effi Helmy Ariffin, Manoj Joseph Mathew, Rosnan Yaacob, Mohd Fadzil, and Mouncef Sedrati and Nor Aslinda Awang Akhir, Hasrizal Shaari, Muhammad Syakir Zufayri Zulfakar. 2018. "Beach Morphodynamic Classification In Different Monsoon Seasons At Terengganu Beaches, Malaysia." *Journal of Sustainability Science and Management* (5): 65–74.

Ehsan, Sofia, Rawshan Ara Begum, Nor Ghani Md Nor, and Khairul Nizam Abdul Maulud. 2019. "Current and Potential Impacts of Sea Level Rise in the Coastal Areas of Malaysia." *IOP Conference Series: Earth and Environmental Science* 228(1).

Fazly Amri Mohd et al. 2018. "Impact of Shoreline Changes to Pahang Coastal Area by Using Geospatial Technology." *Sains Malaysiana* 47(5): 991–97.

Fitri, A., Hashim, R. & Motamedi, S. (2017). Estimation and Validation of Nearshore Current at the Coast of Carey Island, Malysia. Science and Technology, 25(3), 1009–1018.

Gill, J. Ainee, A. M. Anwar, and S. Omar K. 2014. 71 Jurnal Teknologi *Towards the Implementation of Continuous Coastal Vulnerability Index in Malaysia: A Review* Journal Teknologi 4(71): 1-10.

Haditiar, Yudi et al. 2019. "Numerical Simulation of Currents and Volume Transport in the Malacca Strait and Part of South China Sea." *Engineering Journal* 23(6): 129–43.

Han, G., Tian, F., Ma, C. & Chen, Ge. (2021). The geometry of mesoscale eddies in the South China Sea: characteristics and implications. International Journal of Digital Earth. Vol. 14 (4). Pp. 464-479.

Helmy, Effi, and Bin Ariffin. 2018. "Effect of Monsoons on Beach Morphodynamics in the East Coast of Peninsular Malaysia."

J. K. Raj, Ismail Yusoff, and Wan Hasiah Abdullah. 2007. "Past, Present and Future Coastal Changes at the Kuala Kemasin Estuary, Kelantan State." *Bulletin of the Geological Society of Malaysia* 53(June): 75–80.

Jusoh, W. H. W., Tangang, F., Juneng, L., & Hamid, M. R. A. (2014). Numerical modeling of hydrodynamic in southwestern Johor, Malaysia. In AIP Conference Proceedings Vol. 665, pp. 665–670).

Kamarudin, M. K. A., Toriman, M. E., Abd Wahab, N., Rosli, H., Ata, F. M., & Mohd Faudzi, M. N. (2017). Sedimentation Study on Upstream Reach of Selected Rivers in Pahang River Basin, Malaysia. International Journal on Advanced Science, Engineering and Information Technology, 7(1), 35.

Kulkarni, R. R. (2013). Numerical Modelling of Coastal Erosion using MIKE21. Master Thesis, Norwegian University of Science and Technology.

Maruti, S. F., S. Amerudin, W. H.W. Kadir, and Z. M. Yusof. 2018. "A Hydrodynamic Modelling of Proposed Dams in Reducing Flood Hazard in Kelantan Catchment." *IOP Conference Series: Earth and Environmental Science* 140(1);1-8.

Mohtar, Wan Hanna Melini Wan, Siti Aminah Bassa, and Mojtaba Porhemmat. 2017. "Grain Size Analysis of Surface Fluvial Sediments in Rivers in Kelantan, Malaysia." *Sains Malaysiana* 46(5): 685–93.

Mohammad Noor, N., Rahaida Harun, S. N., Zainab, M. L., Mukai, Y., Najma, T. M., & S. S. (2013). Diversity of Phytoplankton in Coastal Water of Kuantan, Pahang, Malaysia. Malaysian Journal of Sciences, 32(1), 29–37.

Dunstan A. P., Aslinda N. A., Ahmad Tarmizi A., Yannie A.B., Zulazman M.L., Ikmalzatul A., Nurul A'idah A.R., Amir Hamzah A.R., Shahdy I., Siti Salihah M.S. & Roslina A.R. 2019. Morphodynamic of Marudu Bay during North East Monsoon (NEM). *Journal Earth Science & Climate Change* 10(4);1-13.

Polagye, B. L., Epler, J. & Thomson, J. 2010. Limits to the predictability of tidal current energy. OCEANS 2010 MTS/IEEE SEATTLE. pp. 1-9, doi: 10.1109/OCEANS.2010.5664588.

Prasetyo, A., Yasuda, M., Miyashita, T. & Mori, N. (2018). Physical modeling and numerical analysis of tsunami inundation in a coastal city. Front. Built Environ. 5:46. doi:10.3389/fbuil.2019.00046

Radzir, N. A. M., Ali, C. A. & Mohamed, K. R. 2018. Physical characteristics and distribution of bottom sediments from the kelantan river delta towards the south China sea continental Shelf, Malaysia. Bulletin of the Geological Society of Malaysia, 66(66), 89–97. doi:10.7186/bgsm66201812.

Rashidi, Ahmad Hadi Mohamed et al. 2021. "Coastal Structures as Beach Erosion Control and Sea Level Rise Adaptation in Malaysia: A Review." *Water (Switzerland)* 13(13): 1–34.

Razak, Mohd Shahrizal Ab, Franciscus Xaverius Suryadi, Nurhamizah Jamaluddin, and Nur Ariffah Zaimah Mohd Nor. 2018. "Shoreline Planform Stability of Embayed Beaches Along the Malaysian Peninsular Coast." *Journal of Coastal Research* 85: 631–35.

Reid, S. K., Tissot, P. E., & Williams, D. D. (2014). Methodology for Applying GIS to Evaluate Hydrodynamic Model Performance in Predicting Coastal Inundation. Journal of Coastal Research, 297, 1055–1065. doi:10.2112/jcoastres-d-13-00160.1

Samaras, Achilleas, Matteo Vacchi, Renata Archetti, and Alberto Lamberti. 2013. "Wave and Hydrodynamics Modelling in Coastal Areas with TELEMAC and MIKE21." (July 2014): 14–19. http://vzb.baw.de/publikationen/vzb_dokumente_oeffentlich/0/tuc_2013_gesamt_rgb_111013.pdf.

Sawczyński, S., & Kaczmarek, L. M. (2014). Modeling Bathymetry Changes in the Coastal Zone – State of Knowledge Analysis. Technical Science, 17(3), 219–233.

Tam, Tze Huey et al. 2019. "Application of Satellite Rainfall Products for Flood Inundation Modelling in Kelantan River Basin, Malaysia." *Hydrology* 6(4).

Tobergte, David R., and Shirley Curtis. 2013. "Hydrodynamic and Sediment Transport Modeling of Deltaic Sediment Processes." *Journal of Chemical Information and Modeling* 53(9): 1689–99.

Toriman, Mohd Ekhwan et al. 2015. "Penilaian Kemasinan Air Menggunakan Pemodelan Model Berangka Hidronamik Di Muara Sungai Selangor, Malaysia." *Malaysian Journal of Analytical Sciences* 19(5): 1109–19.

Voujas, N. (2015). Coastal Hydrodynamics and Sediment Transport Regime of the Central Kerala Coast in Comparison to Southern Kerala. Ph.D. Thesis, Cochin University of Science and Technology.

Wan Ahmad, W. I. & Abdurrahman, S. M. (2015). Kelantan Flood 2014: Reflections from Relief Aid Mission to Kampung Kemubu, Kelantan. Mediterranean Journal of Social Sciences (2015). Vol 6(3). Pp 340 – 344. Doi:10.5901/mjss.2015.v6n3s2p340

Wyrtki, K., (1961). Physical oceanography of the Southeast Asian water. In NAGA Report Vol. 2, Scientific Result of Marine Investigation of the South China Sea and Gulf of Thailand 1959–1961, Scripps Institution of Oceanography, La Jolla, California, 195pp.

Zhang, Hong, S. A. Sannasiraj, and Eng Soon Chan. 2009. "Wind Wave Effects on Hydrodynamic Modeling of Ocean Circulation in the South China Sea." *The Open Civil Engineering Journal* 3(1): 48–61.

Zu, T., Gan, J. & Erofeeva, S. Y. (2008). Numerical study of the tide and tidal dynamics in the South China Sea. Deep-Sea Research I 55 (2008) 137–154.

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