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Introduction Tidal Analysis and Prediction Based on Harmonic MoDEL at Lagos Harbour using U-TAPS

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Keyword: *Tides, Harmonic Analysis, Tidal Prediction, Tidal Constituent, Harbor*

Abstract

The conventionally harmonic analysis is usually used to predict a tide, the amplitude and frequencies are determined from an analysis of measured sea level tide gauge which is a superposition of many sinusoidal constituents known as tidal constituent. Mostly long-term measurement of at least 6 months to 18.6 years are needed and analyzed to form an accurate tidal prediction by using the method of harmonic analysis. This paper presents the method of harmonic analysis for the tidal level records from Lagos Harbour tide gauge station located at the South west of Nigeria. The result obtained from the validation shows that long time water level data that was used is enough to produce an accurate tidal prediction, but the new version of the UTAPS need to be produce to meet up with the current state of the art.

Introduction

The tide is formed as a result of interchanging rise and fall of the water body's covering the rotating planet earth (Mörner, 2019). Tides are formed as a result of the gravitational attraction of the two masses, the moon and the earth on the rotating earth (Na *et al*., 2019). In shallow water and other marine operation mostly, there is a need for accurate tidal level prediction and information for safe marine navigation, coastal engineering-construction, estimates of the sediment's and pollutants transport and disposal, environmental monitoring, mineral resource exploration and offshore construction (El-Diasty *et al.*, 2018). The equilibrium tidal theory which was the attempt to give a proper description of the tidal phenomenon was proposed by Sir Isaac Newton, (Newton, 2008) later an attempt to improve the accuracy of equilibrium theory for the prediction of sea level variation in the open sea by Darwin in 1893 failed to obtain accurate estimates in the condition of near shore complex -bottom topography (Lee, et al., 2007). The method of Determination of harmonic constants by applying the Lease Square and the admiralty technique were proposed by (Doodson, 1957). Following the work of Doodson, the method of harmonic analysis for tidal prediction was mostly employed all around the world. Numerous method for sea water level prediction were established easily by many researchers. Tidalist have changed the model approaches for tidal analysis and prediction from single approach to hybrid model approach in order to improve their forecast (Abubakar et al., 2019) in which the current – state – of – art can be traced to the work of Li 2019 where short data was used to predict tides by hybriding least-squares estimation and inaction method (CAI *et al*., 2018; Li, & Wang, 2019). Sea water level forecast using genetic programming and comparing the performance with Artificial Neural Networks was done by (Ali *et al*., 2010). (Cai *et al*., 2018) used short data of one month to predict two weeks tidal using Normal Time Frequency transformation (NTFTM). The method of Neural Network for tidal forecasts was also used by Tidalist to improve the accuracy of their forecasts by predicting different types of tides. (Tsai *et al.,* 1999; T. Lee *et al.,* 2002; Tsong *et al.,* 2004; W.K. Lee & Resdi, 2014; Meena & Agrawal, 2015). Their method can be effective. However, their approached of technique depends on harmonic parameters and cannot predict non-astronomical tidal level. (Slobbe et al., 2018), uses short tidal data for about six months and was able to determine the Lowest Astronomical Tide (LAT) at the North Sea and Wadden sea by the method of Kalman filter. (El-Diasty et al., 2018) uses one-month sea water level from four different tide gauge station to predict one-month sea water level by hybriding Harmonic Analysis and Wavelength Network. The integrated model outperforms the wavelength method only and harmonic analysis only by about 19.5%, 16.39%, 22.04%, and 18.60% for the four tide gauge stations he used. Muhammad El-diasty concluded that the accuracy of the accuracy performance of the developed hybrid HA and WN model is location independent. (T.-L. Lee *et al.*, 2007). Combine harmonic analysis method with an artificial neural network method for tidal analysis and prediction using hourly sea level data for the year 2000 obtained at the Hillarys Boat Harbour, West Australia. The Lee case study shows that, the combined method adopted allows accurate determination of tidal constituents on the bases of two-month data which is the prerequisite for tidal level prediction.

The main objective of this paper is to show the mathematical model description of harmonic analysis that was used in the developing university technology Tidal Analysis and Prediction software (UTAPS) for Tidal analysis and prediction. Moreover, one of the Nigerian tide gauge stations was used to test the performance of the software.

The paper is organized as follows, after the introduction, the mathematical basis for lease square harmonic analysis methodology is described, the result obtained from UTAPS was illustrated and compared with the observed data. Finally, conclusions were derived based on the result obtain from UTAPS software.

LOCATION OF STUDY AREA AND DATA SOURCE

Lagos Harbour was chosen for this work as it's the only station that its data can be obtained through online sources. The Lagos Harbour provides an entry from the Atlantic Ocean to a network of Lagos lagoons, with Lagos and Lekki lagoons being the major lagoons among these lagoons. The other lagoons are Yewa, Badagry, Ologe, Iyagbe, Kuramo, Apese, Epe, and Mahin lagoons is situated in Lagos State, which is in the South Western part of Nigeria. (Badejo & Akintoye, 2017; Onyema & Opinion, 2009). Lagos lagoon discharges into the Atlantic Ocean through Lagos Harbour. The Lagos Harbour is 0.5 km to 1 km wide and 10km long. The result of the Lagos bathymetric survey in 2008 carried out by the Department of Surveying and Geoinformatics, University of Lagos, shows that the water depth of Lagos Harbour ranges from 4m to 20m, with an average depth of 11m. Water from the Atlantic Ocean moves into the Lagos Harbour during high tides and recedes during low tides (Badejo & Akintoye, 2017).

Figure 1.0 Image of Lagos Lagoon Tide Station

The tidal data used for this work was obtained from University of Hawaii Sea Level Canter http://uhslc.soest.hawaii.edu/data/?rq. The observed tidal data covered a period from January 1, 1994 to December 31, 1995. The obtained online data was divided into two sets, the training set as well as the testing set.

LEASE SQUARE HARMONIC ANALYSIS FOR TIDAL PREDICTION METHOD

The most traditional method use for tidal level prediction is harmonic analysis of lease square which we used in developing University Technology Malaysia Tidal Analysis and Prediction Software (UTAPs). It's based on the principals that long period cyclicities of tide are associated with the astronomical factors like relative positions of the sun, moon, and earth. In harmonic analysis, the astronomical component is expressed as superposition of many sinusoidal constituents with amplitudes and frequencies determined by a local analysis of the measured tide waves. Thus, daily sea level y(t) for certain time t can be represented by a time-dependent function**:**

The observations of water level from tide gauge station can be characterized as the sequence through the assumption that a one-dimensional time series with tidal and nontidal energies can be expressed as,

$$h(t_n) = Z_0 + \sum_{i=1}^{k} R_i \cos(\omega_i t_n - \theta_i) , \qquad (1)$$

Were

$h(t_n) =$ tidal elevation at any given time,

$Z_0 =$ level of tidal elevation,

$R_i =$ nth constituent amplitude,

$\omega_i =$ n-node velocity,

$\theta_i =$ n^{th} phase,

$t_n =$ Time,

$i =$ calculated number of constituents

By using the trigonometric method

$$\cos(\alpha - \beta) = \cos\alpha.\cos\beta + \sin\alpha.\sin\beta \qquad (2)$$

then, equation (1) can be changed to

$$h(t_n) = Z_0 + \sum_{i=1}^{k} R_i \cos(\omega_i t_n).\cos(\theta_i) + \sum_{i=1}^{k} R_i \sin(\omega_i t_n).\sin(\theta_i) \qquad (3)$$

Where $A_i = R_i \cos(\theta_i)$ and $B_i = R_i \sin(\theta_i)$

Then

$$h(t_n) = Z_0 + \sum_{i=1}^{k} A_i.\cos(\omega_i t_n) + \sum_{i=1}^{k} B_i.\sin(\omega_i t_n) \qquad (4)$$

Where

A_i, and B_i = are the ith harmonic component

K = number of harmonic components

t_n = time of observation every hour (-n, -n + 1, ..., 0, ..., n), t = 0 is the time of observation so, the following values can be determined

(1) component of the observation = $h(t_n)$

(2) calculated components = Z_0, A_i, and B_i

(3) specified components = ω_t

MATRICE FORMATION

The formation of matrices was done to make the calculation of the normal equation easier by using a least square estimation method. The normal equations are shown below

$$\sum_{t=1}^{k}\left(Z_0 + \sum_{m=-1}^{n} A_i \cos \omega_i t_n + \sum_{m=-n}^{k} B_i \sin \omega_i t_n \right) = \sum_{m=-n}^{n} h(t_n)$$

$$\sum_{l=1}^{k}\left(Z_0 \sum_{l=1}^{n} \cos \omega_i t_n + \sum_{m=n}^{n} A_i \cos \omega_i t_n \cos \omega_i t_n + \sum_{m=n}^{k} B_i \sin \omega_i t_n \cos \omega_i t_n \right) = \sum_{m=-n}^{k} h(t_n) \sum_{m=-n}^{n} \cos \omega_i t_n \quad (5)$$

by using the normal equation, it is converted to form A matrix form AX = F as follows

$$A = \begin{bmatrix} 1 & \cos \omega_i t_1 & \cdots & \cos \omega_i t_1 & \sin \omega_i t_1 & \cdots & \sin \omega_i t_1 \\ 1 & \cos \omega_i t_2 & \cdots & \cos \omega_i t_2 & \sin \omega_i t_2 & \cdots & \sin \omega_i t_2 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & \cos \omega_i t_n & \cdots & \cos \omega_i t_n & \sin \omega_i t_n & \cdots & \sin \omega_i t_n \end{bmatrix},$$

$$X = \begin{bmatrix} Z_0 \\ A_1 \\ A_2 \\ \cdots \\ A_i \\ B_1 \\ B_2 \\ \cdots \\ B_i \end{bmatrix}, F = \begin{bmatrix} h_1 \\ h_2 \\ \cdots \\ \cdots \\ \cdots \\ h_n \end{bmatrix} \quad (6)$$

Furthermore, by using the matrix equation (6), calculate the value of the parameter on the matrix X with the following equation.

$$\begin{aligned} AX &= F \\ (A^T A)X &= A^T F \\ (A^T A)^{-1}(A^T A)X &= (A^T A)^{-1} A^T F \\ X &= (A^T A)^{-1} A^T F \end{aligned} \quad (7)$$

to define the matrix equation above, then the matrix component is calculated as follows

$$A^T A = \begin{bmatrix} 2n+1 & A_1 & A_2 & \cdots & A_i & B_1 & B_2 & \cdots & B_i \\ A_1 & A_2A_1 & A_1A_2 & \cdots & A_1A_i & A_1B_1 & A_1B_2 & \cdots & A_1B_i \\ A_2 & A_2A_1 & A_2A_2 & \cdots & A_2A_i & A_2B_1 & A_2B_2 & \cdots & A_2B_i \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ A_i & A_iA_1 & A_iA_2 & \cdots & A_iA_i & A_iB_1 & A_iB_2 & \cdots & A_iB_i \\ B_1 & B_1A_1 & B_1A_2 & \cdots & B_1A_i & B_1B_1 & B_1B_2 & \cdots & B_1B_i \\ B_2 & B_2A_1 & B_2A_2 & \cdots & B_2A_i & B_2B_1 & B_2B_2 & \cdots & B_2B_i \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ B_i & B_iA_1 & B_iA_1 & \cdots & B_iA_i & B_iB_1 & B_iB_2 & \cdots & B_iB_i \end{bmatrix} \quad (8)$$

The above component has the following values

$$A_i = \sum_{m=1}^{n} \cos \omega_j t_n$$
$$B_i = \sum_{m=1}^{n} \sin \omega_j t_n$$
$$A_j A_i = \sum_{m=1}^{n} \cos \omega_j t_n . \cos \omega_k t_n$$
$$B_j B_i = \sum_{m=1}^{n} \sin \omega_j t_n . \sin \omega_k t_n$$
$$A_j B_k = \sum_{m=1}^{n} \cos \omega_j t_n . \sin \omega_k t_n \quad (9)$$

In the meantime, the Solution of T AF is as follows

$$A^T F = \begin{bmatrix} \sum_{m=1}^{k} h(t_n) \\ \sum_{m=1}^{n} \cos \omega_1 t_n \\ \sum_{m=-n}^{n} \cos \omega_2 t_n \\ \cdots \\ \sum_{m=1}^{n} \cos \omega_r t_n \\ \sum_{m=1}^{n} \sin \omega_1 t_n \\ \sum_{m=1}^{n} \sin \omega_2 t_n \\ \cdots \\ \sum_{m=1}^{n} \sin \omega_i t_n \end{bmatrix} \quad (10)$$

From the final result of the calculation will be obtained the value of X matrix, as the value of the Zo, Ar, and Br parameters used for the calculation of the amplitude and phase of each calculated tidal constituent.

RESULTS

Two-year data set of Lagos Harbour tide gauge station were obtained via online sources of University Hawaii Sea level Centre from January 1994 to December 1995, and the data were divided into two, that is, 1994 data set was for training (input) while the 1995 data are for comparism. In this study, only November Prediction table as well as graph was shown which can be seen in table1. The graph of the Frequency Residual Periodogram for the constituents used can also be seen in Figure 1, similarly the graph of the residual modelling error can also be seen in Figure 2 while Figure 3 shows the comparism between observed and predicted tide which they are in good agreement. The identification and prediction performances of the model are evaluated by indices of root mean square error (RMSE), with identification RMSE (RMSEIden) and prediction RMSE (RMSEPre), respectively.

$$RMSE_{Iden} = \sqrt{\frac{\sum_{t=1}^{n}\left(y_{Iden}(t) - y(t)\right)^2}{n}}$$

$$MSE_{pre} = \sqrt{\frac{\sum_{t=1}^{n}\left(y_{pre}(t+q) - y(t+q)\right)^2}{n}} \qquad (11)$$

where the identified and actual value of the tidal level at time t are yIden(t) and y(t) while y Pre(t+q) and y(t+q) are the predicted and actual values of the tidal level at time t+q, respectively.

According to Boon III & Kiley (1978) the classification of the tide may be acquired by calculating the ratio of the amplitudes of the harmonic constituents. This value is called the ‘form number (Dietrich & Kalle, 1957; Pugh, 2004) or ‘tidal form factor’. The classification of the observed tide can be determined using the formula

$$F = \frac{K_1 + O_1}{M_2 + S_2}.$$

The tide is then said to be

i. Semi diurnal if $0 \le F \le 0.25$,

ii. Mixed if $0.25 < F \le 3.00$,

iii. Diurnal if $F > 3.00$.

From table1 the computed amplitudes of K1, O1, M2 and S2 were 0.075408, 0.016659, 0.305819 and 0.106646 respectively. Therefore, F was computed as

$$F = \frac{0.075408 + 0.016659}{0.305819 + 0.106646} = 0.2232$$

Since the computed form factor (F) fell between 0 and 0.25, the tide can therefore be classified as semi-diurnal. Moreover, the result obtained using UTAPS software shows that tides in Lagos Harbour are semi-diurnal in nature. The result obtained from the prediction is quite promising and it is in tabular form, which is space consuming, but a sample of the table can be seen in Table2.

Table 1 Constituent used Error Propagation report obtained from UTAPS

NAME	AMPLITUDE	AMPLITUDE ERROR	PHASE	PHASE ERROR
SA	0.759652	0.00702684	250.4929	0.53063
SSA	0.539666	0.00703469	333.4784	0.746105
MM	0.04203	0.00703845	120.6847	9.505237
MSF	0.066711	0.00702772	355.8765	6.021919
MF	0.03943	0.00703345	123.4749	10.10863
2Q1	0.002152	0.00708049	168.2839	73.09434
SIGMA1	0.00525	0.00708392	61.36631	53.45543
Q1	0.005691	0.00708543	137.1469	51.23
RO1	0.001027	0.00708542	44.27709	81.74958
O1	**0.016659**	0.00703745	277.3774	22.90054
MP1	0.001678	0.00703727	158.57	76.58597
M1	0.001706	0.00705924	73.6694	76.41453
CHI1	0.002278	0.00706471	312.2795	72.12637
PI1	0.007636	0.00704017	0.402065	42.67691
P1	0.034845	0.00703902	10.65327	11.42104
S1	0.014495	0.00703841	147.4454	25.90006

K1	**0.075408**	0.00703813	14.85784	5.332273
PSI1	0.026136	0.00703829	287.6078	15.07189
FI1	0.015611	0.00703879	350.4059	24.27003
THETA1	0.006102	0.00709849	136.4453	49.31804
J1	0.007982	0.00709198	276.9675	41.61682
SO1	0.002785	0.00703371	11.47059	68.40255
OO1	0.003747	0.00703229	183.469	61.95367
OQ2	0.004531	0.00703223	83.84526	57.20759
MNS2	0.007789	0.00703339	213.5934	42.08147
2N2	0.015126	0.00708634	313.2458	25.10254
MU2	0.017019	0.00708647	110.0172	22.60404
N2	0.062499	0.00708788	233.1007	6.470163
NU2	0.022616	0.00709063	350.4607	17.40782
OP2	0.057896	0.00703881	189.9202	6.932259
M2	**0.305819**	0.00703807	168.8566	1.318451
MKS2	0.070737	0.00703899	147.3523	5.682942
LAMBDA2	0.01431	0.00709422	291.2891	26.3675
L2	0.010666	0.00709505	317.3575	33.63204
T2	0.027773	0.00703604	300.6895	14.21595
S2	**0.106646**	0.00703532	213.2754	3.774317
R2	0.033054	0.00703497	134.0029	12.01508
K2	0.01733	0.00703476	145.6972	22.09416
MSN2	0.0033	0.00703603	134.3863	64.87559
KJ2	0.004278	0.00703562	183.9962	58.70032
2SM2	0.002694	0.00703604	353.0478	69.05019
MO3	0.001903	0.00703012	178.5796	74.85634
M3	0.001714	0.00703343	134.497	76.30693
SO3	0.002511	0.00703111	101.6993	70.34338
MK3	0.005283	0.00703051	94.15607	53.07268
SK3	0.00149	0.00702872	354.5014	78.02873
MN4	0.004287	0.00702927	323.5295	58.62238
M4	0.01298	0.00703238	209.5398	28.44916
SN4	0.000643	0.00703253	350.3233	84.77965
MS4	0.00687	0.00703	235.23	45.65781
MK4	0.002059	0.00702947	155.6669	73.67718
S4	0.00306	0.00702889	225.3631	66.47349

SK4	0.000308	0.00702876	38.89152	87.48881
2MN6	0.001159	0.00702946	98.55929	80.63392
M6	0.002564	0.00703223	24.23987	69.96816
MSN6	0.000959	0.00703274	121.2345	82.23838
2MS6	0.002174	0.00702989	53.62542	72.81646
2MK6	0.001304	0.00702965	26.95703	79.48752
2SM6	0.001381	0.00702922	75.7774	78.88106
MSK6	0.000404	0.00702872	137.093	86.70848

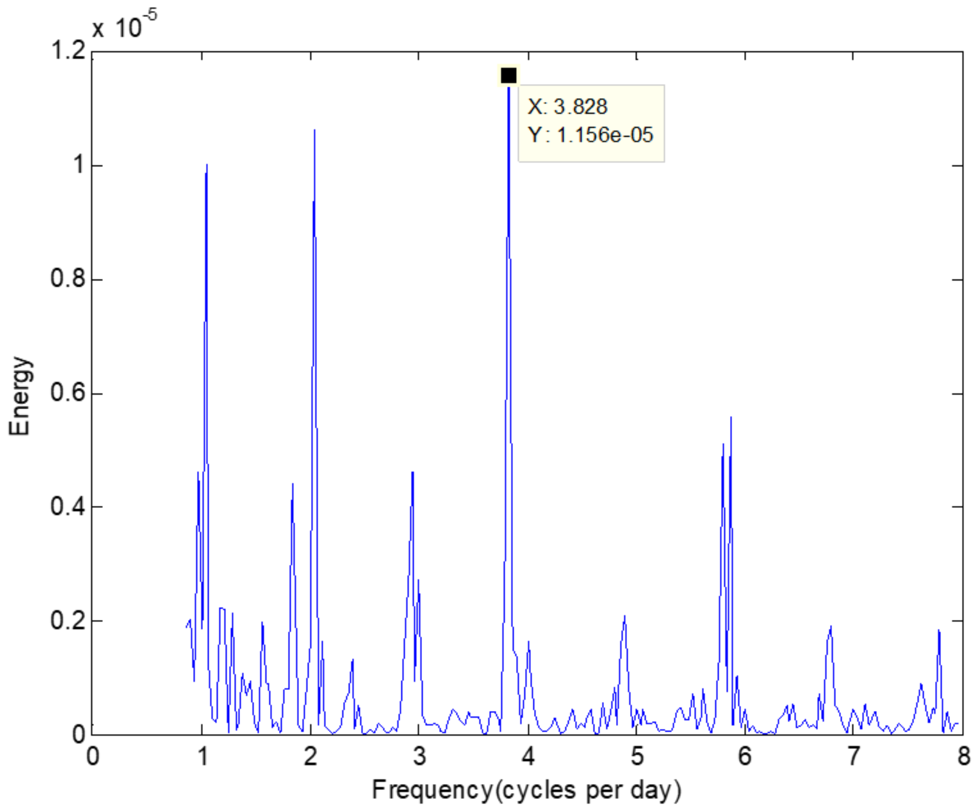

Figure: 1 Frequency Residual Periodogram for the constituents used which was obtained from UTAPS software

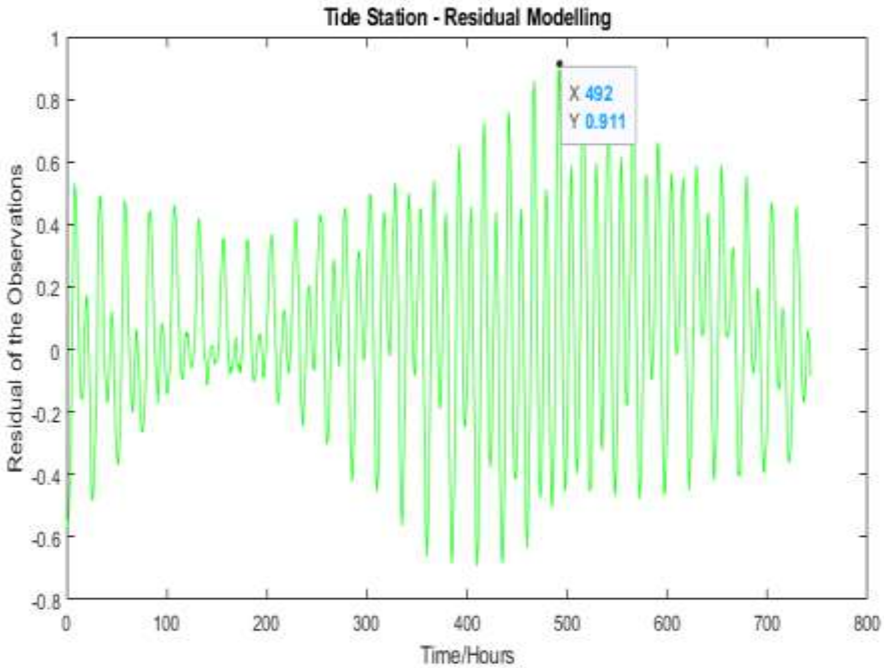

Figure 2 Residual Modelling Error.

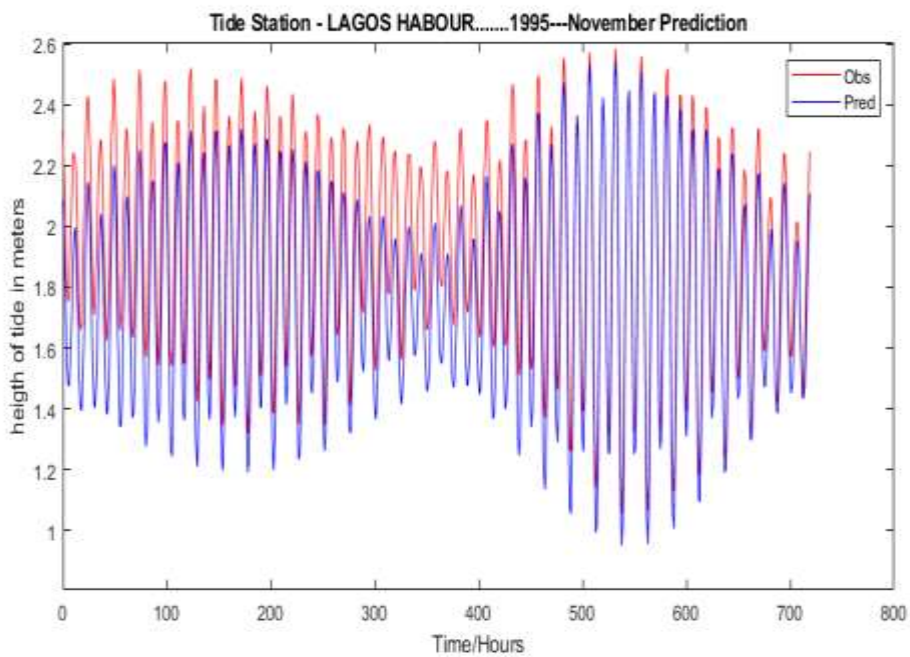

Figure 3 Predicted Tide VS Observed Tide

Predicted water level compared with the observed water level of November 1995 obtained from UTAPS software.

Table: 2 Predicted Tide Table For the month of November, from UTAPS SOFTWARE

Lat 06 26 48 N   Long 03 22 43 E

YEAR 1994   NOVEMBER

HEIGHTS IN METRES

Hour / Date	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.25	2.39	2.40	2.27	2.01	1.69	1.39	1.18	1.12	1.22	1.45	1.75	2.03	2.23	2.32	2.27	2.07	1.78	1.49	1.28	1.21	1.30	1.52	1.83
2	2.14	2.38	2.50	2.48	2.30	1.98	1.60	1.27	1.07	1.04	1.19	1.48	1.83	2.13	2.33	2.41	2.33	2.09	1.75	1.43	1.23	1.18	1.31	1.58
3	1.93	2.25	2.47	2.57	2.51	2.28	1.91	1.49	1.16	0.98	1.00	1.20	1.54	1.91	2.21	2.40	2.45	2.35	2.07	1.71	1.39	1.21	1.19	1.35
4	1.65	2.01	2.31	2.51	2.58	2.49	2.22	1.81	1.39	1.08	0.95	1.00	1.25	1.61	1.98	2.26	2.43	2.46	2.33	2.03	1.66	1.37	1.22	1.23
5	1.41	1.73	2.06	2.33	2.49	2.53	2.42	2.13	1.72	1.32	1.06	0.96	1.06	1.33	1.68	2.02	2.26	2.41	2.43	2.28	1.97	1.64	1.38	1.25
6	1.29	1.49	1.78	2.07	2.29	2.42	2.44	2.31	2.02	1.64	1.29	1.08	1.02	1.15	1.41	1.73	2.02	2.23	2.36	2.36	2.20	1.92	1.63	1.41
7	1.32	1.37	1.55	1.80	2.03	2.20	2.30	2.31	2.18	1.92	1.59	1.30	1.14	1.12	1.25	1.49	1.75	1.99	2.17	2.27	2.27	2.13	1.89	1.64
8	1.47	1.40	1.45	1.59	1.78	1.96	2.09	2.17	2.17	2.06	1.84	1.57	1.35	1.23	1.24	1.35	1.54	1.75	1.94	2.09	2.18	2.18	2.07	1.88
9	1.68	1.54	1.48	1.51	1.60	1.73	1.86	1.96	2.03	2.05	1.97	1.80	1.59	1.43	1.34	1.34	1.42	1.56	1.72	1.88	2.01	2.10	2.12	2.04
10	1.89	1.73	1.61	1.54	1.53	1.57	1.66	1.76	1.85	1.93	1.97	1.93	1.80	1.64	1.51	1.43	1.41	1.45	1.56	1.69	1.83	1.95	2.05	2.09
11	2.03	1.91	1.77	1.65	1.56	1.51	1.52	1.59	1.68	1.78	1.87	1.93	1.92	1.83	1.70	1.58	1.49	1.45	1.47	1.55	1.68	1.81	1.94	2.05
12	2.09	2.05	1.93	1.79	1.64	1.53	1.46	1.47	1.54	1.64	1.76	1.88	1.95	1.94	1.86	1.74	1.61	1.51	1.45	1.47	1.56	1.69	1.84	1.98
13	2.08	2.11	2.06	1.93	1.76	1.59	1.46	1.40	1.43	1.53	1.66	1.80	1.93	1.99	1.98	1.89	1.75	1.60	1.49	1.45	1.49	1.60	1.76	1.92
14	2.06	2.14	2.14	2.05	1.88	1.68	1.50	1.38	1.36	1.43	1.57	1.74	1.89	2.01	2.05	2.01	1.89	1.72	1.56	1.46	1.45	1.53	1.68	1.86
15	2.03	2.14	2.18	2.14	2.00	1.79	1.57	1.39	1.32	1.34	1.47	1.66	1.85	2.00	2.09	2.10	2.02	1.86	1.66	1.50	1.43	1.47	1.60	1.79
16	1.99	2.14	2.22	2.21	2.11	1.92	1.67	1.44	1.30	1.28	1.37	1.55	1.78	1.98	2.11	2.16	2.13	1.99	1.79	1.58	1.45	1.43	1.52	1.70
17	1.92	2.12	2.24	2.27	2.20	2.04	1.80	1.53	1.33	1.24	1.28	1.44	1.67	1.91	2.10	2.19	2.20	2.12	1.93	1.70	1.51	1.42	1.45	1.59
18	1.81	2.04	2.22	2.29	2.27	2.15	1.94	1.66	1.40	1.24	1.22	1.32	1.53	1.80	2.03	2.18	2.24	2.21	2.07	1.85	1.62	1.46	1.42	1.50
19	1.68	1.92	2.14	2.27	2.31	2.24	2.07	1.81	1.53	1.30	1.20	1.23	1.40	1.65	1.91	2.11	2.23	2.25	2.17	1.99	1.75	1.55	1.43	1.44
20	1.57	1.78	2.02	2.20	2.29	2.28	2.17	1.95	1.67	1.41	1.24	1.20	1.29	1.50	1.76	1.99	2.16	2.24	2.22	2.09	1.89	1.66	1.49	1.42
21	1.48	1.65	1.87	2.07	2.21	2.26	2.21	2.06	1.82	1.55	1.33	1.21	1.23	1.38	1.60	1.85	2.05	2.17	2.22	2.16	2.00	1.79	1.59	1.46
22	1.44	1.54	1.72	1.93	2.09	2.19	2.20	2.12	1.94	1.69	1.45	1.28	1.23	1.30	1.47	1.70	1.91	2.07	2.16	2.17	2.08	1.91	1.71	1.54
23	1.46	1.48	1.60	1.78	1.95	2.08	2.14	2.12	2.02	1.83	1.60	1.39	1.27	1.27	1.38	1.56	1.76	1.94	2.07	2.13	2.11	2.01	1.83	1.65
24	1.51	1.47	1.52	1.64	1.79	1.94	2.03	2.07	2.04	1.93	1.74	1.53	1.37	1.30	1.33	1.45	1.62	1.80	1.96	2.06	2.10	2.07	1.96	1.80
25	1.63	1.51	1.48	1.53	1.64	1.77	1.89	1.98	2.00	1.97	1.87	1.70	1.52	1.38	1.34	1.38	1.50	1.65	1.82	1.96	2.05	2.09	2.06	1.96
26	1.79	1.62	1.52	1.48	1.51	1.59	1.71	1.83	1.92	1.96	1.95	1.86	1.71	1.54	1.41	1.38	1.41	1.51	1.66	1.83	1.97	2.07	2.12	2.10
27	1.99	1.81	1.63	1.51	1.44	1.44	1.51	1.64	1.78	1.89	1.96	1.97	1.90	1.75	1.58	1.45	1.40	1.41	1.50	1.65	1.84	2.00	2.12	2.19
28	2.17	2.04	1.84	1.63	1.47	1.36	1.34	1.42	1.57	1.74	1.90	2.01	2.04	1.98	1.82	1.63	1.48	1.39	1.38	1.47	1.65	1.86	2.06	2.21
29	2.29	2.26	2.10	1.87	1.61	1.39	1.25	1.23	1.33	1.53	1.75	1.95	2.09	2.14	2.07	1.89	1.67	1.48	1.36	1.34	1.45	1.66	1.91	2.14
30	2.31	2.39	2.34	2.15	1.86	1.55	1.29	1.14	1.13	1.27	1.52	1.79	2.04	2.20	2.25	2.16	1.96	1.69	1.46	1.32	1.31	1.44	1.68	1.97

CONCLUTION AND RECOMMENDATION

CONCLUTION

The computed tidal height using UTAP software which was built based on the harmonic analysis method is in Good agreement with the measured data. But, the state-of-art considered hybridization of models prevails more accurate result than the single model. The limitation of UTAPS software is not exceptional to the need of long hourly tidal data for reliable accuracy of tidal prediction when predicting a long period of water height. There is a need to improve the accuracy of the software. In general, new version of the software should be developed.

RECOMMENDATION

This research work come up with the following recommendations:

i. There is a need for the established of more permanent tide gauge stations along the Nigerian coastline.

ii. Up to date online tidal observation should be made available to the public and research institutions.
iii. The accuracy of the developed software (UTAPS) based on this research can be used on Coastal waterways, oil and natural gas production, recreation tourism, fisheries and environmental habitat and the software accuracy is also high enough to support marine activities around Lagos harbour.
iv. Government and non-governmental agencies should put more effort in making tidal observation and analyse of water level around the Nigerian coastal waters to better understand the hydrodynamic forces operating in the Nigerian coastal environment as its one of the Sustainable Development Goals of united nation to achieve a better and more sustainable future for all by 2030**.**

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