TREND ANALYSIS OF GLOBAL POSITIONING SYSTEM TIDAL DATUMS ALONG THE NIGERIAN COASTLINE

[1]Aboh, C. E.; [2]BIU, Emmanuel Oyinebifun; [3]Nkpordee, Lekia

[1]*Institute of Geosciences and Environmental Management,*
Rivers State University, Nkpolu-Oroworukwo,
Port Harcourt, Rivers State, Nigeria

[2]*University of Port Harcourt, Choba, Rivers State, Nigeria*

[3]*Department of Mathematics/Statistics,*
Ignatius Ajuru University of Education, Rivers State, Nigeria

Abstract

This study determine the trend component of global positioning system tidal datums obtained along the coast of Nigeria. For the purpose of this study, we had to designate some stations as control stations and others as subordinate stations along the Nigeria Coastline. The control stations are stations considered to have 19 year record while the subordinate stations have information of less than 1 year. The control stations are Lagos-Apapa, Warri and Bonny Ports. The subordinate stations are Lagos-Bar, Excravos, Forcados, Akassa-Nun River Entrance, Brass river entrance, Port Harcourt Port, and Calabar Port. Three trend curve were fitted on the water level movement from West-south to south-south of the Nigeria coastline. Evaluation of the Results showed that the estimation control and subordinate stations daily Mean sea level is 4.79m and 5.62m respectively. The highest mean water level is at Brass river entrance with 7.49m, while lowest mean water level is at Warri Port with 3.45m. Then, the identify trend curve from the GPS Levels for the stations is a cubic trend variability along the Nigeria Coastline. This result seem to indicate a semi-diurnal to mixed semidiurnal behavior along the Nigeria Coastline.

1. Introduction

Tidal datums are planes of reference derived from the rise and fall of oceanic tides. There are numerous datum planes, each is used for a specific purpose or helps describe a tidal phenomenon. Such planes are the planes of Mean High Water, Mean Low Water, and Mean Sea Level etc. Tidal datums traditionally have been used as surfaces from which to reference depths on nautical charts and elevations on maps Tidal datums are used for a number of important purposes. They provide reference surfaces for navigational charts (Hannah, 2009); as an indicator of climate change (Pugh, 2004) and as the basis for defining various coastal cadastral jurisdictional boundaries (Baker and Watkins, 2001).

GPS or the Global Positioning System, (Fig 1.1) is a global Navigation satellite system that provides location, velocity and time synchronization (Keys, 2020). It is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel. The satellite system consist of a constellation of 24 satellites in a six Earth centered orbital plane, each with four satellites, orbiting at 13,000 miles/(20,000 km) above the earth and travelling at a speed of 8,700 mph (14,000km/hr). Orbital height is 20,180km.

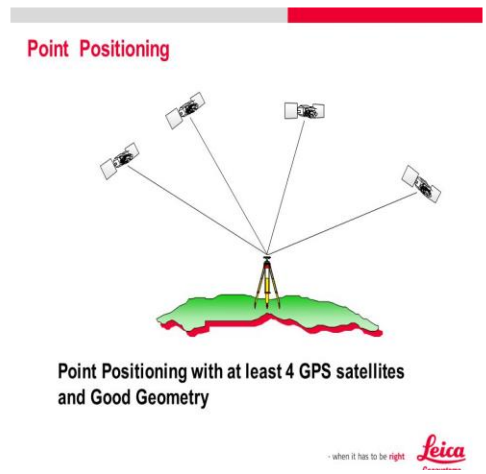

Fig 1.1: GPS Satellite

GPS is made up of three segments:

1. Space Segment: The satellites circling the Earth, transmitting signals to users on position and time of day.
2. Ground control: The control segment is made up of Earth based monitor stations, master control stations and ground antenna. Control activities include tracking and operating the satellite in space and monitoring transmissions. There are monitoring stations on almost every continent in the world, including North and South America, Africa, Europe, Australia and Asia.
3. User equipment: GPS receiver and transmitters including items like watches smart phones and telematics devices.

Most countries now have their GPS installed in space. The Russian GPS is the GLONASS, the European version is GALILEO, the USA is NAVSTAR (GPS) and recently the Chinese Beidou has been a launched. Other regional GPS versions by India is known as Indian Regional Navigation system (IRNSS) and the Japanes regional Navigation system (Quasi-Zenith Satellite System (QZSS) (GPS, Wikipedia, 2019).

1.2 Statement of the Problem

Rising sea levels are already affecting communities in Nigeria, and it is becoming obvious that impacts due to sea level rise may continue to increase in the future Awosika *et al,* (1992). Rising sea levels may inundate new areas of the coastline and increase the frequency and magnitude of coastal floods. The entire Nigerian Coast has been subjected to the devastating effects of flood and erosion. Solutions for such sea level rise (or disasters) can be solved from accurate monitoring trend component movement along coastline of Nigeria.

1.3 Aim and Objectives of the Study

The aim of this study is to identify trend curve of GPS tidal datums collected along the Nigeria Coastline. Its specific objectives are:

1. Estimate the descriptive statistics of the GPS tidal datums along the coast of Nigeria using chart.
2. Fit three trend curve on Global Positioning System tidal datums (i.e. Linear, quadratic and Cubic trend).
3. Identify the best trend curve using R-square statistics and Akaike Information criteria. (AIC).

1.4 Justification

This study was to measure the trend in Mean Highest Water Level by GPS methods which will help shows the behavior of sea activities along the Nigeria coastline. Therefore the establishment of trend component along the coast of Nigeria will form the basis for further researches in the physical description and modeling of the Nigerian coast and offshore zone.

1.5 Significance of the Research

Recent survey practice is to tie water level measurements to temporary gauges for adhoc measurements by engineers. Monitoring mean sea level rise, the effects of global warming, protecting the environment and the coastline require accurate modern techniques for evaluating sea level rise and the determination of associated tidal datums become imperative.

This research is aimed at using modern technique (called GPS method) for tidal datum determination and trend component identification in solving the problems of environmental monitoring and to determine sea boundaries for the Nigerian coastline.

1.6 Scope of the Research

The GPS method was used in determining tidal datums. The method is used to improve accuracy and time of survey, have all been employed. According to Goring (2007) traditional method have their limitations in terms of accuracy, cost and time of survey. The GPS leveling, which measures ellipsoidal height differences can overcome many of the problems associated with traditional leveling method, both requires a high quality field observation and processing technique.

Trend component identification method in time series was used to determine tidal characteristics features along the Nigeria Coastline.

2. Literature Review

The National Ocean Survey (NOS 2000) of USA uses two methods of simultaneous comparison computations to estimate the 19-year tidal datums, "as near as possible" from shorter measurements.

Water level datums at different locations are local vertical datums which may vary considerably within a geographical area. A geodetic datum is a reference surface relative to which heights are determined. The North American Vertical Datum of 1988 (NAVD 88) is the accepted geodetic vertical datum of the National Spatial Reference System (NSRS) for the conterminous United States and Alaska and is officially supported by NGS, (SPDC, 2015).

Table 2.1 shows the relationship between various datums and there uses and the height they represent.

The relationships of tidal datums to geodetic datums (Table 2.1) such as NAVD 88 and to ellipsoid heights (above GRS 80 ellipsoid) support many hydrographic, coastal mapping, and engineering applications including the monitoring of sea levels, the deployment of GPS Electronic Chart Display and Information Systems (ECDIS), and the NOS Vertical Datum (VDatum) transformation tool, etc. NOAA Special pulication, NOS CO-OPS 2 state that existing Geodetic Bench Marks (GBM) in the vicinity (up to 1.6 km (1 mile) leveling distance) of a water level station (primary and subordinate) shall be searched for and recovered.

An orthometric level connection and ellipsoidal GPS tie is required at each water level station (primary and subordinate) that has at least one Geodetic Bench Mark located nearby (within 1.6 km (1 mile) leveling distance of a water level station).

Andrew and Paul, (2010) investigated Water Level Measurement and Tidal Datum Transfer Using High Rate GPS Buoys. It was found out that using a GPS buoy to measure water levels offers many advantages over traditional techniques with its ability to determine heights relative to an absolute reference frame. While large scale GPS buoys have been used for long-term datum determination (e.g. Arroyo-Saurez et al., 2005), there has been little research involving light-weight designs for short-term tidal datum transfers. However, Abidin (1999) did suggest that small systems using GPS did show potential for this type of application. One of advantage of this technique was to determine the viability of GPS buoy technology in transferring tidal datums. In particular, the ability of a high rate GPS buoy to measure the sea level was verified by determining its precision and accuracy relative to tide gauge observations. Furthermore, it aimed to demonstrate how accurately a tidal datum could be transferred using the sea levels estimated by the GPS buoy.

The emphasis has been on the use of short term records to determine datums and also the techniques for datum transfers from one station to the other. Apart from the traditional methods highlighted by some researchers, new techniques have been highlighted. Such techniques are the use of the GPS to measure tidal datums and accuracies taking into cognizance that GPS heights relate to a geodetic reference frame known as the ellipsoid. This method required a translation from one datum to the other with transformation models for it to be transferred to a tidal datum. Various techniques like the use of buoys have also been introduced.

According to Robert and Merry (2001), the GPS techniques has further improved the accuracy of determining tidal datums and it is becoming the preferred method in term of accuracy, which make more research on its application are being carried out.

Other adhoc researches in this area were undertaken in the monitoring of Tidal Datums consistency for Nwaniba River in the Niger delta region of Nigeria by Bannabas Morakinyo and kehinde Sunmolu (2019). The study was confined to the Nwaniba River. Two sets of tidal data from 10/05/2007 to 10/06/2007 and 10/05/2017-10/06/2017 were observed three times a day. This study was to measure the trend in Mean Highest Water Level, Mean Lowest Water Level and Mean Water Level. On the Global front a number of researches on tidal datum and its computations have been carried out by various authors and professional institutions in the field of marine surveys.

In recent times, the Nigerian Navy has been publishing tide tables for about 18 stations along the coast with reference to tidal benchmarks. With this development, this research will address the issue of determining the trend variability of tidal datums along the coastline of Nigeria and select the best/suitable trend curve that described the movement of water level along the Nigerian coastline.

Table 2.1: Definitions of Height

Datum	Height	Example	Creation	Characteristics	Datum transformation
National or continental	Orthometric	NAVD 1929, NGVD 1988	Traditional survey and leveling, using bench marks, and tied to tide station(s)	Used for maps on land.	
Geodetic	Geoid	EGM2008, EGM 96	Created from Geoid model from satellite observations with radar altimeters		NGA provides grids with differences between WGS84 ellipsoid and EGM

					2008 and EGM96, and works worldwide
Ellipsoidal	Ellipsoidal	WGS84	Derived from horizontal datum and satellite measurements	Instruments such as GPS or ICESAT measure elevation relative to the ellipsoid. These can either be transformed to a geodetic or national datum, or left as ellipsoidal.	NGA provides grids with differences between WGS84 ellipsoid and EGM 2008 and EGM96, and works worldwide
Tidal	Orthometric	Local chart datum from nautical chart with tide gauge	Created from tide record from 18 year Metonic cycle	Applies to a single tide station with epoch, and updated roughly every 18 years. Difficult to extend from the tide gauge. Not used for maps on land.	NOAA Vdatum provides some capabilities for this in the US Can be on MSL, MLLW, or potentially others

3. Materials and Methods

This research is on the more recent GPS method for measuring tidal datums, which provides speedy and accurate datum measurements based on established similar characteristics within the tide gauge station and the differential leveling that accompanies it. Further development on this method is the use of differential Global positioning system (DGPS) with a monitoring station and a base station. The use of this method which applies to this work is for improved accuracy in determining datums and trend component identification to determining the movement characteristics along the Nigerian coastline.

3.3 Sources of Data

SPDC provide what we have as a GPS survey which corresponding with the water level benchmarks along Nigeria coastline.

3.3.1 Data Processing Procedures

Data collected from the field are processed and tabulated before tidal datums are computed.

3.3.2 Tidal Datum Computation Procedure

Two stages are paramount before a tidal datum could be determined.

i. The tidal Epoch, which is the average of 18.6 years data series should be defined;

ii. Secondary or tertiary determination provides the comparison of the means of tides to obtain an 18.6 years equivalent mean.

3.3.3 Time Series Plot

The plot reveals slow, moderately steady or fast growth of a daily/monthly fluctuation of a tidal station series. It displays observations on the y-axis against the x –axis on equally spaced intervals (Micro-Excel and Minitab, 2018).

Trend Analysis Y_t

A time series may have a linear pattern, a quadratic trend and seasonality and trend altogether in a particular series. However, in some situations, the total mean of the data could reflect the pattern. The least square estimation technique is the most frequently used mother of any specific sequence to find the pattern. Linear regression equations of the forms predict the pattern

$Y_t = \beta_0 + \beta_1 t$ linear trend (3.1)

$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2$ quadratic trend (3.2)

$Y_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3$ cubic trend (3.3)

where

$\beta_o\ \beta_1\ \beta_2\ \beta_3$ are the regression parameters, t is the observed station points (t =1,2,3, …, N) N is the number of observations and y_t is the observed time series (or tidal stations daily mean sea level obtained by GPS method); Etuk, & Uchendu (2009).

3.3.4 Model Specification: This research will use the linear trend model, quadratic trend model, exponential trend model, and S-cure model. Let Z_t be the time series, then

The Linear Trend Model

The linear trend model is used by default in trend analysis:

$$Z_t = \alpha_0 + \alpha_1 t + \mu_t \quad (3.4)$$

The average change from one period to the following time t is represented in this model.

Model for linear forecasting:

$$Z_t = \alpha_0 + \alpha_1 t \quad (3.5)$$

The Quadratic Trend Model:

$$Z_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \mu_t \tag{3.6}$$

Quadratic forecasting model:

$$Z_t = \alpha_0 + \alpha_1 t + \alpha_2 t^2 \tag{3.7}$$

The Exponential Trend Model:

$$Z_t = \alpha_0 (\alpha_1)^t + \mu_t \tag{3.8}$$

Exponential forecasting model:

$$Z_t = \alpha_0 (\alpha_1)^t \tag{3.9}$$

The S-curve Trend Model:

The S-curve model fits the Pearl-Reed logistic trend model. This is how the case when the series follows an S-shaped curve is described. The following is the model:

$$Z_t = \frac{10^a}{(\alpha_0 + \alpha_1 \alpha_2{}^t)} \tag{3.10}$$

where

α_0 = Estimated Z intercept

α_1 = Estimated linear effect on Z

α_2 = Estimated quadratic effect on Z

3.3.5 Trend Model Accuracy Measures

Suppose our output data set is denoted by $Y_t, 1, 2, ..., n$. To determine the best method in modelling and for computing tidal datum transfer, we will estimate its parameters and use the parameters to obtain the estimated output time series as $\hat{Y}_t, 1, 2, ..., n$. The estimated errors are given by

$$\hat{e}_t = Y_t - \hat{Y}_t, \; t = 1, 2, ..., n \tag{3.11}$$

The three most commonly used measures to determine the best methods on a single data set are (Hyndman and Athanasopoulos, 2021):

(I) Mean Absolute Error (MAE)

$$MAE = \frac{1}{n}\sum_{t=1}^{n} \left| \hat{e}_t \right| \qquad (3.12)$$

(II) Mean Absolute Percentage Error (MAPE)

$$MAPE = \left[\frac{1}{n}\sum_{t=1}^{n} \left| \frac{\hat{e}_t}{X_t} \right| \right] x\,100 \qquad (3.13)$$

(III) Mean Square Error

$$MSE = \frac{1}{n}\sum_{t=1}^{n} \hat{e}_t^2 \qquad (3.14)$$

R-Square (R^2)

R^2 is a measure of the proportion of variability in the data set that is accounted for by a regression model. It assumes that every independent variable in the model helps to explain variation in the dependent variable (y) and thus gives the percentage of explained variable if all independent variable in the model affect the dependent variable (y). The R^2 statistic is defined as

$$R^2 = 1 - \frac{SSE}{SST} \qquad (3.15)$$

where

$SS_T = \sum(y_i - \bar{y})^2$ is the total sum of square.$SS_E = \sum(\hat{y}_i - \bar{y})^2$ is the residual sum of squares.

y_i and $\hat{y}_i$are the original modelled data values.

Akaike Information Criteria (AIC)

Akaike (1983) developed a manner that's called Akaike Information criteria. The form of this information is given under:

$$AIC = n \ln\left[\frac{SSE}{n}\right] + 2(k) \qquad (3.16)$$

where; N = Sample size, K = Number of parameter and SSE = Sum of square error.

3.4 DGPS Field Data Acquisition Procedures:

The DGPS equipments were usually calibrated at Shell Petroleum control stations known as ZVS and logged with average co-ordinate gotten. However, equipment used for this research at site include vehicles 4 wheel drive (2 numbers), leveling instruments total stations, and DGPs receives (2 numbers).

- **Methodology for DGPS calibration**

The calibration was done on ZVS celebration measurement (Fig. 3.1). C & C Correction was purchased and correction codes entered in the C-set up software. The geodetic parameter were entered into the system software. The GPS antenna offset was set to zero. The antenna was placed on top of the ZVS centre pin, after which logging was activated for 15 mins. This process was repeated for the second GPS at the second geodetic station benchmark.

1. Set up was carried out at the control station with the Dual frequency GPS to achieve a higher accuracy.
2. Equipment was powered and geodetic data required in the DGPS were input at the control station.
3. GPS was set up at the subordinate station with all the necessary data required in order to acquire data.
4. It was ensured that no tree or building etc is covering the GPS.
5. The two systems are switched on to acquire data taking into consideration the availability of enough satellites to get a good geometry for position computation.

Accuracy attained is a function of the time taken to carry out the observations etc.

Processing of Data

1. Acquired data is downloaded and processed.
2. The required Geodetic data using the processing software for each equipment were input as follow:-

Input in the System

1. Transformation parameters from the client
2. Height of instrument measured in the field
3. DGPS processing software

Geodetic Parameters

The following geodetic datum, spheroid and mapping projection parameters were used.

WGS 84 Definition

Datum WGS 84

Spheroid CLARKE 1880

Axis: 6,378,249.145m. Inverse flattening 293.465; (SPDC, 2015).

Local Datum definition

Datum Minna (Nigeria); spheroid

Clarke 1880 (Modified): semi major axis. 6378249. 145m

Semi-minor axis: 6,356. 314. 86955m Inverse; Flattening 293, 465,

Eccentricity squared: 0.006803 511 283, (SPDC, 2015).

Datum shift parameters from WGS 84 to minna datum.

Dx = + 111.916m, Dy = + 87.852m, Dz = - 114.499m, Rx = - 1.87527 secs,

Ry = - 0.20214 secs, Rz = - 0.21935 secs and Scale = - 0.03245.

Projection Parameters

Projection name: Nigerian mid-belt; projection

Type transverse Mercator; zone #31 and #32

Central meridian 4^{0} 00’ 0.00” East

Latitude origin = 8^{0} 30^{1} 00^{11} North (SPDC, 2015).

False easting at central meridian: 670553.983m; False

Northing at latitude of origin: 0.000 m;

Scale factor at central meridian: 0.99975

Measurement: meters

Fig 3.1: ZVS Calibration Monument (ZVS 3003 Shell Control Point, Nigeria)

Relationship between tide gauge DGPS at control station, tide gauge bench mark at subordinate station and datum level

A permanent tide gauge station was set up at the control station and subordinate station and were simultaneously measured with static DGPS. The tide gauge DGPS were also connected to the tide gauge benchmark at the subordinate station by precise leveling to establish the vertical information.

4.Results

This section shows results of the descriptive analysis and trend component prediction result and discussion of the variables results. Data for GPS survey of the Nigerian Coastline as proposed was collected from stations daily mean sea level by GPS method. The control stations variables are Apapa Lagos, Warri and Bonny ports tidal datums; while subordinate stations variables are Lagos bar, Excravos, Forcados, Akassa-Nun River Entrance, Brass River, Port Harcourt and Calabar. The plots and descriptive statistics of the control and subordinate stations was achieved. Then, GPS Method Analysis Estimated Mean Sea Level (EMSL) for the Control and Subordinate stations was done. Efforts were made at obtaining data, from relevant organization in Nigeria such as the water level observations collected from in Nigeria Navy (2020) and efforts to get SPDC in get the data both that didn’t work out. However, SPDC provide what we have as a GPS survey which corresponding with the water level benchmarks along Nigeria coastline.

The analysis of the GPS data carried out for this research is based on the GPS readings from Shell Nigeria Limited, which provided location, elevation and mean sea level information for some stations. Comparison and accuracy determination between the control and subordinate stations GPS tidal datum cannot be achieved. However, by observations of the chart (Figure 4.1) relating the control and subordinate stations GPS tidal datum to obtained MSL highest and lowest. Also, the GPS tidal benchmarks between control and subordinate stations was estimated.

Daily Mean Sea Level of the water level at the control station and at the tide subordinate stations were estimated in Table 4.1 and 4.2 below using GPS Method. Then, several maps and diagrams showing the GPS level along the Nigeria coastline in Appendix D.

- **Control station**

Table 4.1: Estimation of control stations daily sea level by GPS Method

Stations	Apapa Lagos	Warri Port	Bonny port		Mean
Daily Mean Sea Level	4.15m	3.45m	6.78m	MHWc	**4.79m**

Source: SPDC field measurement, (2015)

- **Subordinate station**

Table 4.2: Estimation Subordinate Stations Daily Sea Level by GPS Method

Stations	Lagos Bar	Excravo s	Forcados Bar	Akassa-Nun River Entrance	Brass River Entrance	Port Harcourt-Port	Calabar Port		Mean
Daily Mean Sea Level	3.50m	4.09m	5.40m	6.08m	7.49m	6.35m	6.41m	MHWs	**5.62m**

Source: SPDC field measurement, (2015)

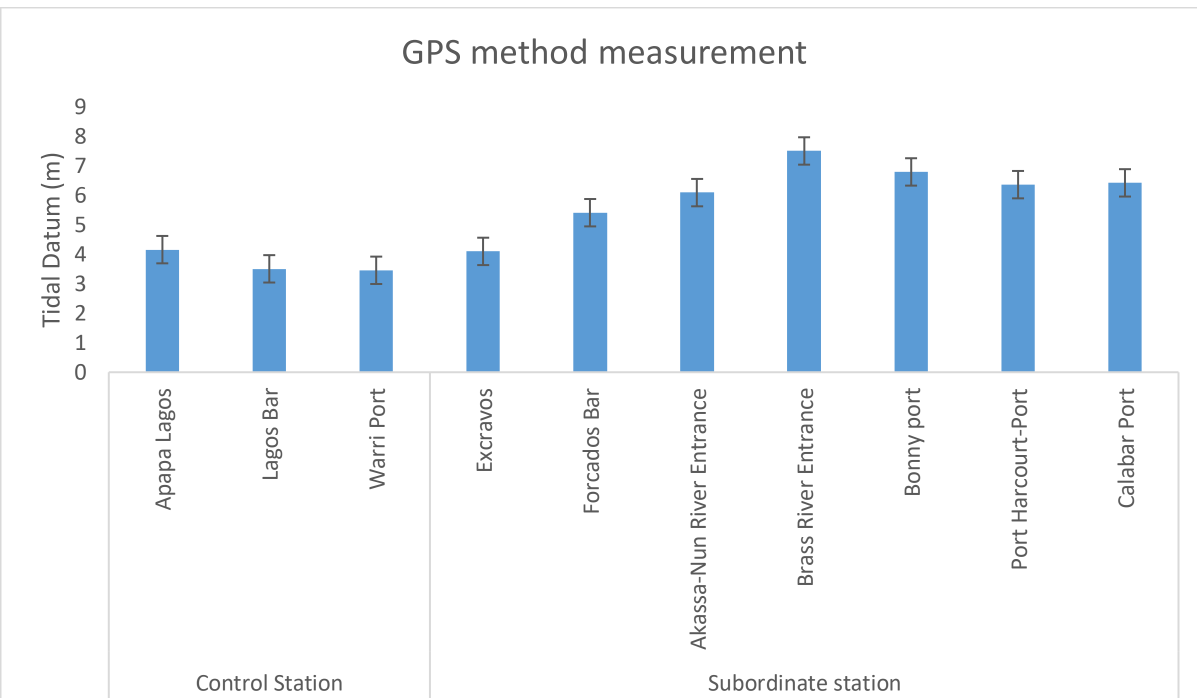

Figure 4.1: GPS Method MSL Measurement at the Control and subordinate stations (Bar chart with standard errors bar).

Table 4.3: Daily Sea Level Estimated from West-South to South-South Coasts

West-South coasts					South-South coasts				
Apapa Lagos	Lagos Bar	Warri Port	Excra vos	Forcados Bar	Akassa-Nun River Entrance	Brass River Entrance	Bonny port	Port Harcourt-Port	Calabar Port
4.15	3.5	3.45	4.09	5.4	6.08	7.49	6.78	6.35	6.41
Approx.		**4.11m**				**6.62m**			

Note: Station array from Apapa Lagos to Calabar Port to monitor the trend component

GPS height comparisons were conducted using trend analysis (Linear, Quadratic and Cubic trend) in Table 4.4 and Figure 4.2.

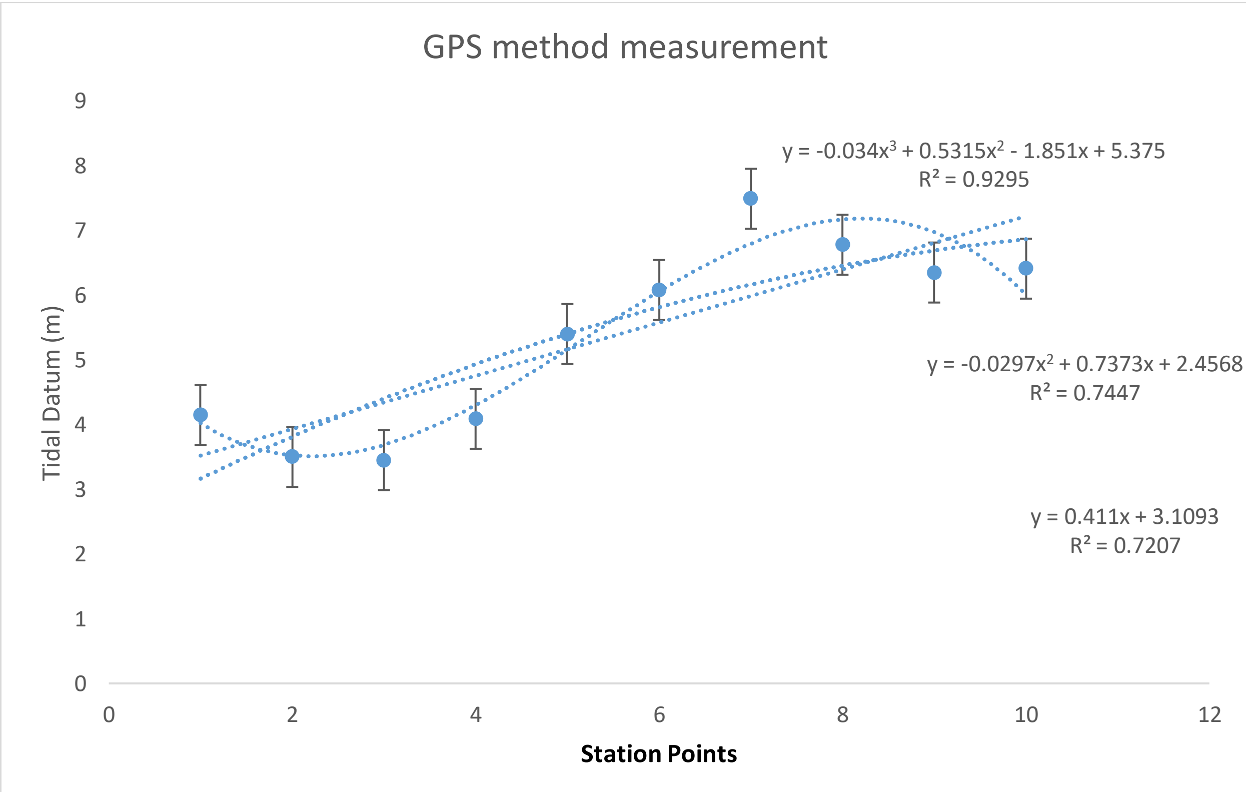

Figure 4.2: Trend Analysis of GPS Method MSL Measurement at the Control and subordinate stations

Comparing the results in Table 4.1 and 4.2: The daily Mean Sea Level elevation at the subordinate stations [5.62m (MHW_S)] is higher than the daily Mean Sea Level elevation at the control stations [4.79m (MHW_S)]. The difference between the MSL at the control stations and at the subordinate stations is 0.83m. Note; the highest sea level elevation among the control stations is Bonny station with 6.78m, while the highest sea level elevation among the subordinate stations is Brass River Entrance with 7.49m.

The variability is slightly higher with 6.62m in the South-South coasts, while West-South coasts is slightly less in variations with 4.11m in Table 4.3. The highest tidal level was observed at Brass River Entrance station and the lowest was at Lagos Bar station also in Table 4.3.

These GPS method measurements are represented in the associated Bar chart with standard errors bar in Figure 4.1. The trend variability of the tidal datum around the coast of Nigeria is a cubic trend, which explained 92.95% of the variation across the Nigeria coastal region (Figure 4.2).

Table 4.4: Trend Analysis Models Parameters and Accuracy Measures

Trend Analysis Y_t Model	Parameter Estimates (p-value)	R-square	Mean Square Error	AIC	Accuracy Measures		
					MSD	MAD	MAPE
Linear	β_0= 3.109 (0.001**) β_1= 0.4110 (0.002**)	72.07%	0.6752		0.5402	0.6511	12.7811
Quadratic	β_0= 2.457 (0.0042*) β_1= 0.737 (0.117) β_2= 0.0297 (0.444)	74.47%	0.7053		0.4937	0.5803	12.0165
Cubic	**β_0= 5.375 (0.001**)** **β_1= -1.851 (0.037**)** **β_2= 0.532 (0.010**)** **β_3= -0.0340 (0.007**)**	**92.95%**	**0.2273**		**0.4930**	**0.5792**	**12.0001**

Footnote: **-Sig. at 5% and Cubic trend curve is the best Model. Hint;**

Y_t = 5.375 - 1.851 t +0.532 $t^2 - 0.0340\ t^3$

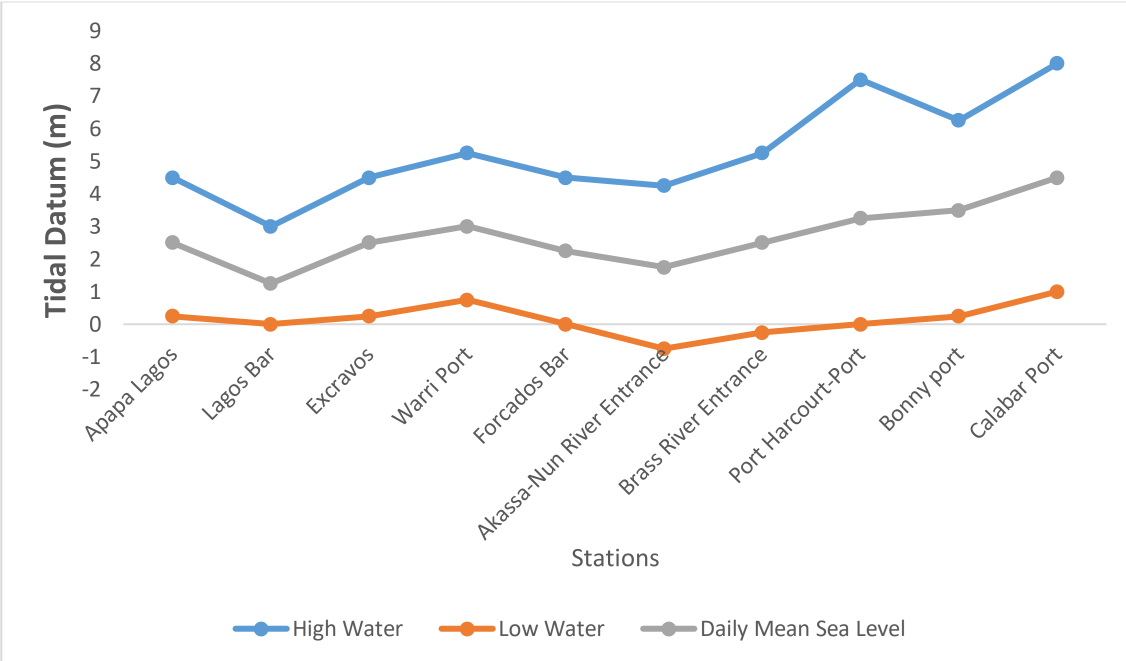

Figure 4.3: Variability Plot of Daily Mean Sea Level, High and Low Water along the Nigeria Coastline.

5. Conclusion

It is clear that the tidal datums collected by the global positioning system (GPS) methods along the Nigeria coastline environments exhibit a larger variation. Since highest mean water level is at Brass river entrance with 7.49m, while lowest mean water level is at Warri Port with 3.45m. This indicates a high variation between of the Chart Datum around the country. The variability is slightly higher (6.62 m) in the South-South coasts, while and West-South is having slightly less variations (4.11m). This might be due to the ocean circulation pattern induced by South-West and South-South monsoon. The three trend curve were fitted on the water level movement from West-south to South-South of Nigeria. The identify trend curve from the GPS sea level measurement for the stations is a cubic trend variability along the Nigeria Coastline. This shows a behavior of rise and fall along the Nigeria Coastline which is mainly semi-diurnal to mix semidiurnal.

References

1.Abidin, H. Z. (1999). *Monitoring Sea Level Using GPS*. In: Proceeding International Seminar on Application of Seawatch Indonesia Information System for Indonesian Marine Resources Development. Jakarta, March 10-11 1999. Available at: http://seawatch.50megs.com/gambar/10.pdf

2. Andrew, M and Paul, D. (2010). *Water Level Measurement and Tidal Datum Transfer Using High Rate GPS Buoys*. School of Surveying, Otago University Dunedin, New Zealand.\

3. Arroyo-Saurez, E. N., Mabey, D. L., Hsiao, V. and Phillips, R. (2005). *Implementation of a*

Positioning and Telemetry Buoy to Determine Chart Datum for Hydrographic Survey Applications. In: ION GNSS 18th International Technical Meeting of the Satellite Division. Long Beach, CA, USA, 13-16 September 2005. Available at: http://op.gfzpotsdam.de/altimetry/SSG_buoys/

4. Awosika, L .F., Gregory, French T., Rolert, J., Nicholls, & Ibe, C.E. (1992). *The impacts of sea level rise on the coastline of Nigeria:* In Proc. IPCC Symposium on the Rising Challenges of the Sea (pp. 14 19). Magaritta.

5. Badejo, O. T., Olaleye, J.B., & Alademomi, A. S. (2014). *Tidal characteristics and sounding datum variation in Lagos State*. International journal of Innovative Research and Studies, 2(1):455-456,

6. Baker, R. F. & Watkins, M. (2021, March 5). *Guidance Notes for the Determination of Mean High Water Mark for Land Title Surveys*. New Zealand Institute of Surveyors. https://www.surveyors.org.nz

7. Baker, R. F., & Watkins, M. (1991). *Guidance Notes for the determination of mean High water mark for land title survey.* New Zealand Institute of Surveyors wellington. https://www.surveyors.org.nz

7. Barnabas Morakinyo and Kehinde Sunmonu (2019). *Monitoring of Tidal Datum Consistency for Nwaniba River in the Niger Delta*. Journal of Geosciences and Geomatics, , Vol. 7, No. 1, 1-8.

8. Box, G. E. P., Jenkins, G. M., and Reinsel, G. C. (1994). *Time series analysis: forecasting and control* (3rd ed.). Prentice Hall.

9. Box, G.E.P. & Jenkins, G. M. (1976). *Time series analysis: forecasting and control*, (Rev. ed.) Holden Day.

10. Chang, C & Tseng, L. (1999). *A Geocentric Reference System in Taiwan*. Survey Review, 35(273): 195-203.

11. Chang, C. (1995). *Monitoring of tide gauge heights in Western Europe by GPS. [PhD monograph,* University of Nottingham]. SearchWorks Catalog. https://searchworks.universityofnottingham.edu/view/1123392

12. Chang, C. C. & Sun, Y. D. (2004). *Application of a GPS-based method to tidal datum transfer.* The Hydrographic Journal, *112*:15-20.

13. Chang, C., Lee, H. W. & Tsui, F. (2002). Preliminary test of tide independent bathymetric measurement based on GPS.*Geomatics Research Australasis, 76*:23-36.

14. Chatfield, C. (2004). The Analysis of Time Series; An introduction (6th ed.). Chapman and Hall/CRC Press Company Boca Raton.

15. Duxbury, Alyn, C. & Alison, B. (1989). *An introduction to the world's oceans*. Brown Publishers.

16. Etuk, E.H. and Uchendu B. A. (2009). *Basic Statistics with Application 2nd edition*. Duke press

17. Fay, M. P., & Proschan, M. A. (2010). *Wilcoxon–Mann–Whitney or t-test? On Assumptions for Hypothesis Tests and Multiple Interpretations of Decision Rules*. Statistics Surveys, *4*:1–39.

18. Gill S. H., & Schultz, J. R. (Eds.) (2001).*Tidal Datums and Their Applications.* Silver springs,

19. Goring, D. (2007). *Transferring a survey Datum Across Water*. Mulgor consulting Ltd, Christ Church. http://www.tideman.co.nz/survey.html

20. Hyndman, R.J. and Athanasopoulos, G. (2021). *Forecasting: Principles and Practice*, Third Edition. OTexts: Melbourne, Australia. OTexts.com/fpp3 https://www.otexts.org/fpp3

21. International Hydrographic Bureau (IHB) (1998). *Standards for hydrographic surveys (*4th ed.) Special Publication

22. Kelecy, T. M., Born, G. H., Parke, M. E, & Rocken, E. (1994). *Precise mean sea level measurement using GPS*. Journal of Geophysical Research, 1(2):23-27

23. Lanmbden, D. W. & de Rijcke, I, (1996). *Legal aspects of surveying water boundaries*. Carswells. Liu, Y. C. (2000*). Mathematical Models for Hydrographic Datum Transfer*. Acta Geodaetica et Cartograohica Sinica, *29*(4)310-316.

24. Maloney, Frank, E., Ausness, & Richard, C. (1974). *The use and legal significance of the mean high water lines in coastal boundary mapping North Carolina.* Law Review, 55(2): 185-273.

25. Marmer, A. (1951). *Tidal datum planes*, special publication No. 135. Silver Springs.

26. Marshall, A. & Denys, F. (2008). *Water Level Measurement and Tidal Datum Transfer Using High Rate GPS Buoys.* FIG Working Week.

27. National Ocean Service. (2000) *Tidal Datums and Their Applications* (pp. 112). NOAA Technical Report. NOS Coops 1. Centre for operational oceanographic products and services. Silver Spring.

28. National Ocean Survey (NOS) (1976). *Hydrographic Manual* (4th ed.) Silver Spring.

29. National Ocean Survey (NOS) (2000a). *Tidal Datums and Their Applications.* Special Publication NOS CO-OPS 1, Silver Spring. National Ocean Survey (NOS) (2000b). NOS Hydrographic Surveys Specifications and Deliverables. Silver Spring,

30.National Oceanic & Atmospheric Administration (2009). *Estimation of Vertical Errors in Datum; the Chesapeake Bay*. NOAA http://vdatum.noaa.gov/docs/errorest_chesapeake.html

31.National Oceanic & Atmospheric Administration, (2007). *Topographic and Bathymetric Data Considerations: Datums, Datum Conversion Techniques, and Data Integration Part II of A Roadmap to* *a Seamless Topobathy Surface*. NOAA Technical Report NOAA/CSC/20718-PUB. http://www.csc.noaa.gov/topobathy/

32. National Oceanic and Atmospheric Administration, (2003). *Computational techniques for tidal datums handbook.* NOAA special publication NOS CO-OPS 2.

33. Nichols, E. & McLaughlin, J, (1984), *Tide mark or tidal datum: The need for an interdisciplinary approach to tidal boundary delimitation*, Report from Departmentof Surveying Engineering, University of New Brunswick.

34. NOAA's National Ocean Service, (2013, July 06). US Department of Commerce, National Oceanic and Atmospheric Administration. "What is the difference between a nautical mile and a knot?" NOAA's National Ocean Service. http://oceanservice.noaa.gov/facts/nauticalmile_knot.html.

35. Paul, M. (1978). "*The tides of the Planet Earth* (1st Edition). William Clowes and Sons Publisher,

36. Pugh, D. (2004). *Changing Sea Levels. Effects of Tide, Weather and Climate.* Cambridge University Press.

37. Pugh, D. T. (2004). *Changing Sea Levels: Effects of Tides, Weather, and Climate*. Cambridge, Cambridge University Press.

38.Schone, T. (2001) *Final Report SSG 2.194 GPS Water Level Measurements*. Special Study Group 2.194: GPS Water Level Measurements, International Association of Geodesy (IAG).

39.Robert, Z and Merry, C L (2001). '*First Results for the GPS Survey of South African Tide Gauge*.' GPS Solutions, 5(2), 78-86.

40.The National Tidal Datum Convention, (1980). U.S. Dept. of Commerce, National Ocean and Atmospheric Administration. National Ocean Survey.

41. Thomson, R. E and Emery, W. J. (2014). *Data Analysis Methods in Physical Oceanography* (3rd Edition.)

42. United Nations Convention on the Law of the Sea (1982), Article 5, 1833 U.N.T.S. 397 [LOSC]. http://www.un.org/depts/los/convention_agreements/texts/unclos/part2.htm).

43. US Army Corps of Engineers (USACE) (2001). *'Hydrographic Surveying*.' Manual No. 1110-2 1003, Alexandria, Virginia.

44. US Army Corps of Engineers (USACE) (2001). *Hydrographic surveying* (pp.1110-2-1003). Alexandria

45. Wood, F J. (1976). *The Strategic Role of Perigean Spring Tides in Nautical History and North*

American Coastal Flooding. Silver Springs.