TROPOSPHERIC MODELLING IN GNSS OBSERVATIONS

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PRESENTATION OUTLINE

Introduction

AIM & OBJECTIVES
IMPACT OF TROPOSPHERIC DELAY ON GNSS SIGNAL
PROBLEM STATEMENT
SCOPE OF THE PROJECT
METHODOLOGY
FIELD OBSERVATIONS & PROCESSING
ANALYSIS OF RESULTS
CONCLUSION AND RECOMMENDATION

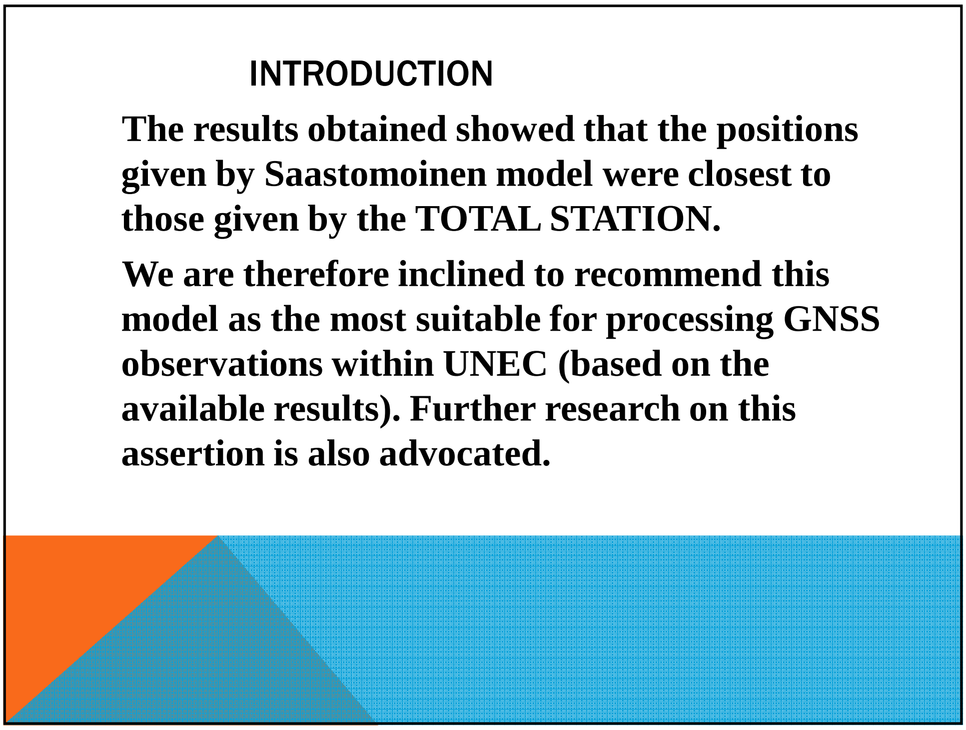
INTRODUCTION

High precision GNSS measurements are required for many scientific applications such as the establishment of geodetic control networks, the monitoring of crustal deformation, strengthening of geodetic networks, as well as vertical control networks, etc.

These networks serve to control topographic mapping as well as cadastral, engineering, and other surveys, and the determination of sea level changes. It is of importance to develop the proper strategies and techniques for GNSS observation and data processing to effectively enhance the accuracy of coordinates based on GNSS measurements. Tropospheric effect is one of the GNSS error sources.

INTRODUCTION

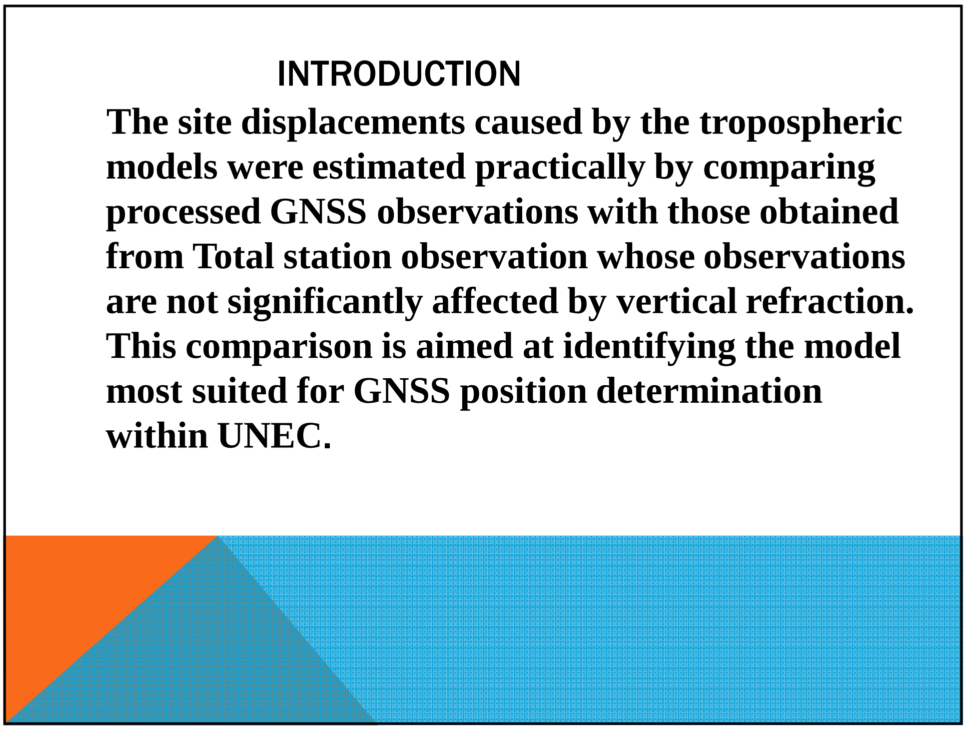
It can cause significant site displacement during the GNSS observation. Thus to study the effect of the troposphere on GNSS position determination, dual frequency GNSS observations were done in static mode at three stations (NI02, NI03 and DPR 773) located within University of Nigeria Enugu Campus (UNEC) and processed using four tropospheric models namely Essen & Froome, Saastromoinen, Hope/Field and simplified Hopfield. The data was also processed without any tropospheric model (No Model).



INTRODUCTION

The results obtained showed that the positions given by Saastomoinen model were closest to those given by the TOTAL STATION.

We are therefore inclined to recommend this model as the most suitable for processing GNSS observations within UNEC (based on the available results). Further research on this assertion is also advocated.



INTRODUCTION

The site displacements caused by the tropospheric models were estimated practically by comparing processed GNSS observations with those obtained from Total station observation whose observations are not significantly affected by vertical refraction. This comparison is aimed at identifying the model most suited for GNSS position determination within UNEC.

PROBLEM STATEMENT

One of the factors limiting the accuracy of position determination by GNSS Observations is the tropospheric delay. Therefore, proper compensation is required, using a standard tropospheric model. In this project, we studied the accuracy that will be achieved when processing GNSS data with different standard models and the effect of these models on position determination with GNSS satellites using observation done within University of Nigeria Enugu Campus.

AIM AND OBJECTIVES

The aim of this project is to determine the best standard tropospheric model that will be used in post-processing of GNSS data using observations done within the University of Nigeria Enugu Campus.

OBJECTIVES

To determine the impact of tropospheric delay on GNSS observation.

To compare the pillar positions derived from the use of different tropospheric models to process GNSS observations.

By comparing with position determination with a total station instrument.

SCOPE OF THE PROJECT

This project is limited to the modeling of the effects of the troposphere on GNSS observations. The effects of the ionosphere are not modeled.

METHODOLOGY

To study the effect of tropospheric delay on GNSS observations. Leica GNSS+1200 dual frequency GPS receiver was used to observe three selected stations within the University of Nigeria Enugu Campus(NIO2,NIO3 and DPR773) in static mode at the epoch rate of 30 seconds and a period of three hours (3hrs) at each station.

These observations were done in the first week of November and December, 2012. The data were later processed using different standard tropospheric models (Saastomoinen, Hopfield, Essen and Froome and Simplified Hopfield).Leica TSO6 Total Station was later used in order to compare with the coordinates given by the different tropospheric models.

The model that is closest to the total station coordinates was taken as the best model within UNEC.

METHODOLOGY

In this study, the coordinates given by the total station were used as the true value(expected values).This is because it was assumed that total station observations to reflectors located on terrestrial points(endpoint of the baseline) were not affected by as much vertical refractions are estimated by the tropospheric models under study. The reason for this assumption is that both the total station instrument and the reflector are usually locate within the same segment or platforms/height layer of the troposphere, hence tropospheric effect is equal at both ends of the line.

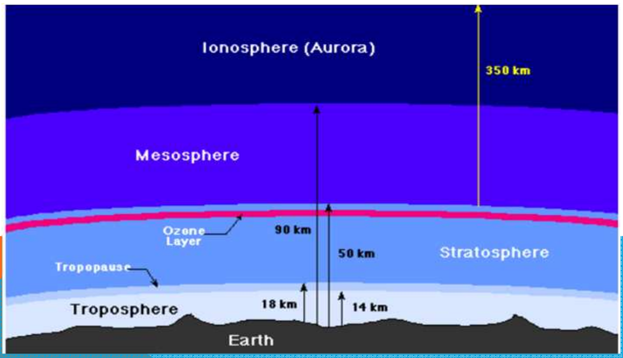
LITERATURE REVIEW

The atmosphere of the Earth is a layer of gases surrounding the planet Earth that is retained by Earth's gravity.

Several layers can be distinguished in the atmosphere, based on characteristics such as temperature and pressure compositions.

Layers of the atmosphere

(http://csep10.phys.utk.edu/astr161/lect/earth/astmosphre.html)



LITERATURE REVIEW CONTINUED

The troposphere, lower part of the atmosphere close to the earth surface, is 9 km over the poles and 16 km over the equator (Sickel, 2008) and extends from the sea to about 50 km skywards.(Hofmann et al., 2001).

It is considered as a neutral atmosphere. This region has an index of refraction that varies with altitude. The index of refraction is slightly greater than unity, causing an excess group delay in the signal waveform beyond that of free space.

Hence it is regarded as a non-dispersive region affecting the L1 and L2 signals by the same amount.

Due to the highly variable tropospheric water vapor content, it is difficult to achieve desired accuracy in this region (Ahn et al., 2006).

LITERATURE REVIEW

The tropospheric delay is a function of elevation and altitude of the receiver which depends on factors such as atmospheric temperature, pressure and relative humidity.

It is not frequency-dependent as is the case with the ionosphere and cannot be eliminated through linear combination of L1 and L2 observations (Satirapod et al, 2005).

Several global tropospheric models such as the Saastamoinen model, Hopfield model, Eseen and Froome have been empirically developed and employed in GPS timing receivers to correct for the tropospheric delay.

LITERATURE REVIEW CONTINUED

TROPOSPHERIC EMPIRICAL MODELS

ESSEN AND FROOME MODEL

In 1951, L. Essen and K.D. Froome used a microwave interferometer to study the refractive indices of the air and its principal constituents. Using the method of Pound (1947), they set both cavities of the interferometer in resonance. They evacuated them and replaced the vacuum by the gas to study at different temperatures. The refractive index of air is then obtained by an extrapolation formula

$$N(p,T,e)=(n-1)\times 10^6=\frac{77.64}{T}\times(p-e)+\frac{64.68}{T}\times\left(1+\frac{5748}{T}\right)\times e \quad \text{............2.2.1}$$

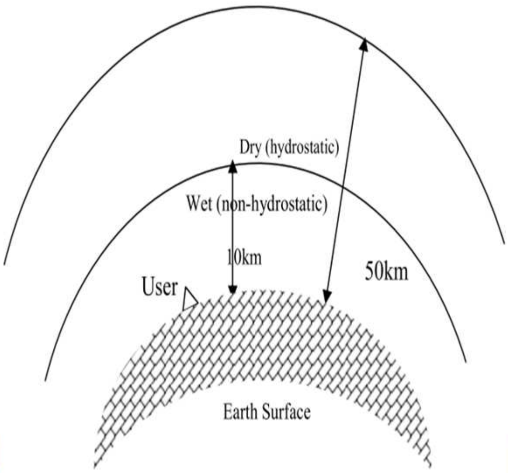
This is the classical Essen and Froome formula. Both the atmospheric pressure p and the water vapor pressure e are in hectopascal [hPa] and the atmospheric temperature T is in Kelvin [K].

SAASTAMOINEN MODEL.

Saastamoinen (1973) applied the gas laws to refractivity by considering the atmosphere as a mixture of dry air and water vapour.

$$D_z^{trop}==\frac{0.002277}{\cos z}\left[p+\left(\frac{1255}{T}+0.05\right)p_w-B\tan^2\right]+{}_{\delta R} \quad \text{..................2.2.2}$$

Where z = zenith angle of satellite, P = pressure (mbar), T = temperature (K),wP = partial pressure of water vapor (mbar) trop zD = tropospheric path delay in metres B and Rδ are the corrections that depends on height (h) of the station and z.



Schematic diagram of the Dry and Wet components of the troposphere,

LITERATURE REVIEW CONTINUED

HOPFIELD MODEL

In the late 1960s, the British scientist Dr. Helen Hopfield based her study of the atmosphere innumerous experiments around the globe and gained a profound understanding of the atmospheric mass movements. From 1969 onwards she devised three successively improve models for the atmospheric refractivity. She assumed that the troposphere could be separated into isotropic layers. Thus she empirically derived a model for the hydrostatic refractivity (Hopfield, 1969).

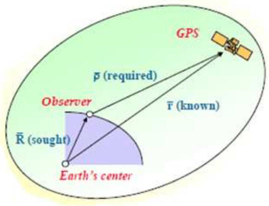
$N_h^{trop}(z) = N_h^{trop}(0) \times [\frac{(zh-z)}{zh}]^4$……………………………2.2.3

SIMPLIFIED HOPFIELD MODEL

Some years later, Dr. Helen Hopfield modified her model by taking into account the curvature of the atmosphere, thus using the modulus of the position vector r rather the altitude z of considered volume element. Considering eq. (2.2.3) but introducing the radius of the Earth , one has

$N_h^{trop}(z) = N_h^{trop}(0) \times [\frac{(rh-r)}{rh-RE}]^4$……………………………2.2.4

POSITION DETERMINATION WITH GNSS



The basic principle of GNSS positioning is similar to the terrestrial principle of resection by distances to known control points. If you know the distance to three points relative to your own position, you can determine your own position relative to those three points. From the distance to one satellite we know that the position of the receiver must be at some point on the surface of an imaginary sphere which has its origin at the satellite. By intersecting three imaginary spheres the receiver position can be determined.

STUDY AREA

UNEC ENUGU CAMPUS

GPS FIELD OBSERVATION DESIGN AND PLANNING

The following considerations were taken in this work:

Accuracy:

GPS manufacturer specifications indicate various levels of accuracy achievable by various GPS receivers based on the type of the receiver, observation session and the observation techniques employed. Nominal accuracy of static mode is ± (3 to 5mm + 1ppm).

Obstruction:

Another factor considered in designing for field observation is the clear view of the satellite on the selected stations. In this project I made sure that there is clear view during the time of observation.

GPS FIELD OBSERVATION DESIGN AND PLANNING

Recording rate PLANNING:

This represents the rate at which satellite measurements are stored. This rate is often termed the data rate or epoch rate. Recording rate also depends on the occupation period, techniques employed as well as processing options.

In this project, the recording rate of 30 second, were used for static observations respectively

GPS OBSERVATION PROCEDURE

In this project, GPS observation was carried out in the static mode because we are interested in tropospheric effect on GNSS observations.

STEP- BY – STEP SETTING UP OF GPS INSTRUMENTS.

Prior to these observations, the Leica dual frequency GPS 1200+ was set up on NIO2 station for initialization as follows;

Leica tripod was set up approximately over the NIO2 station marker.

The tribrach mounted and leveled on tripod.

Through the optical plummet, the tribrach was leveled over NIO2 station markers.

The antenna was screwed onto the carrier and check was performed to ensure that the tribrach was still level.

GPS OBSERVATION

The two batteries were inserted into the receiver and the receiver was hung on one of the tripod legs using the hook on the rear unit.

The compact flash internal memory was used to store the survey observation.

The receiver was connected to the antenna using the antenna cable and port ANT on the receiver.

The “PROG” key on the Rx 1200 is pressed for at least 2 seconds to switch on the receiver and the receiver is ready for operation

TOTAL STATION OBSERVATION

Total station (TS06) was used to observe the stations used for this study. The two stations used for orientation in this observation were NIO3 and NIO4.The observation procedure is as follows:

Step 1. Set a total station on NIO2 and press “ON” key to start the instrument.

Step 2. Level the instrument by pressing .

Step 3. After leveling, select ‘Prog’ from the main menu of the instrument and press enter.

Step 4. From the ‘Prog’ menu select surveying using “F1” key and set job, set station and set orientation sequentially.

Step 5. In the job menu, set the job title and operator.

TOTAL STATION OBSERVATION

Step 6. In the set orientation menu, select coordinates by pressing “F2”. In the “orientation with coordinate” menu, enter back sight point identity (BS Pt ID) as NIO4 and press enter key. Enter easting northing and height (i.e. ENH). Press OK and orientation is set.

Step 7. Put a reflector at the target station (NIO4) and bisect it. Compare the coordinate obtained from the target with its known value and note their difference.

Step 8. Take foresight to other inter-visible points from the instrument station.

Step 9. Change instrument station if the need arises and repeat step 1-3, 6-9.

Step 10. Continue this process until all desired points are coordinated

STEP-BY-STEP GPS DATA PROCESSING WITH LGO SOFTWARE

Step 1. Save the CORS RINEX data in a folder on the desktop.

Step 2.launch the LGO software by double clicking on it and Leica Geo office window opens.

Step 3. Create new project Icon. In the project management window, right-click in space of the window and select new from the drop items that pops up.

In the “new project” window, type the name of the project in “project name” slot and select where to store the project in the location slot. Ensure that averaging method “weighted”, time zone ‘1’ and coordinate system “WGS84” were selected.

Step 4. Import the observed data and the CORS RINEX data.

From the main menu click on ‘Import’ and from the dropdown items click on “Raw Data”

From the import raw data window browse to the location of the observed data, select the data and click import.

GPS OBSERVATION

In assign data to the project window that displays, select setting tab and check the 'GPS' and "merge intervals".

Double click on "Use all" and select the epoch rate of 30s was set for static. Click on GPS tab to uncheck any observation that is not necessary; click on display field icon at the bottom of the window to generate field book for the observation. Click assign and close the window. The observed points imported into LGO are viewed in the form.

To import CORS data, click also on the import and click on the raw data. Navigate to the location of the CORS data and select it. In the import data window, change the file type to "RINEX files" select the CORS data and click on Import" select the project and click on assign" click close.

Step 5. Processing of GPS Data

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The GPS data are displayed in the GPS-Proc. tab where the long bars (in red) indicates the CORS station, the short (in green) ones indicates observations to be processed.

Click on hammer tools, 'select mode reference' on the main menu of Leica Geo-office and click on all the CORS station bars in the Madu project window.

Click on "select mode rover "and click on the observation bar.

The reference bars 'turn red while the observation bars turn green

Step 6. Set the processing parameter

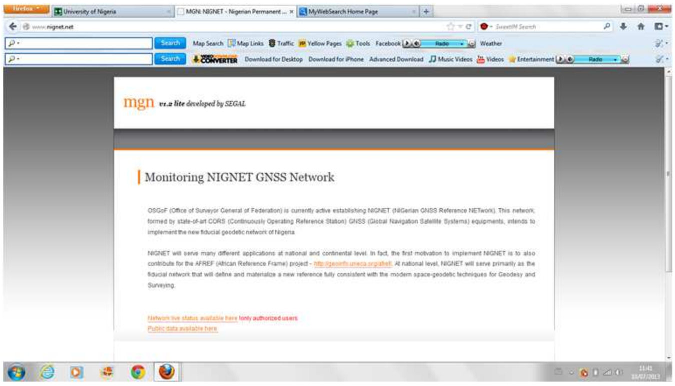
Click on the processing parameter icon and set the following parameters:

- ✓ Cut off angle 15º
- ✓ Ephemeris-Broadcast
- ✓ Fix ambiguities up to 300km
- ✓ Minimum duration for float solution 300 seconds
- ✓ Sampling rate – use all
- ✓ Tropospheric model – Saastomoinen
- ✓ Ionospheric model – automatic
- ✓ Minimum distance – 100km
- ✓ Maximum baseline length – 700km
- ✓ Processing mode – all baseline

Check processing report at the appendices for other parameters.

Step 7. After setting the GPS parameter, click on the GPS-Proc. icon and the result is displayed showing baselines, points, and parameter and report folders.

DOWNLOADING GNSS DATA FROM CORS & PROCESSING



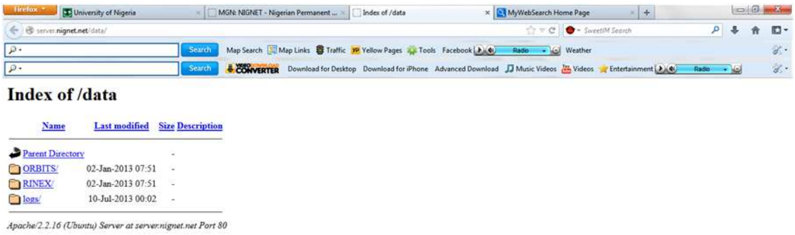
Monitoring NIGNET GNSS Network

OSGoF (Office of Surveyor General of Federation) is currently active establishing NIGNET (NIGerian GNSS Reference NETwork). This network, formed by state-of-art CORS (Continuously Operating Reference Station) GNSS (Global Navigation Satellite Systems) equipments, intends to implement the new fiducial geodetic network of Nigeria.

NIGNET will serve many different applications at national and continental level. In fact, the first motivation to implement NIGNET is to also contribute for the AFREF (African Reference Frame) project - http://geoinfo.uneca.org/afref/. At national level, NIGNET will serve primarily as the fiducial network that will define and materialize a new reference fully consistent with the modern space-geodetic techniques for Geodesy and Surveying.

Network live status available here (only authorized users)
Public data available here

The website to download CORS data is www.Nignet.net



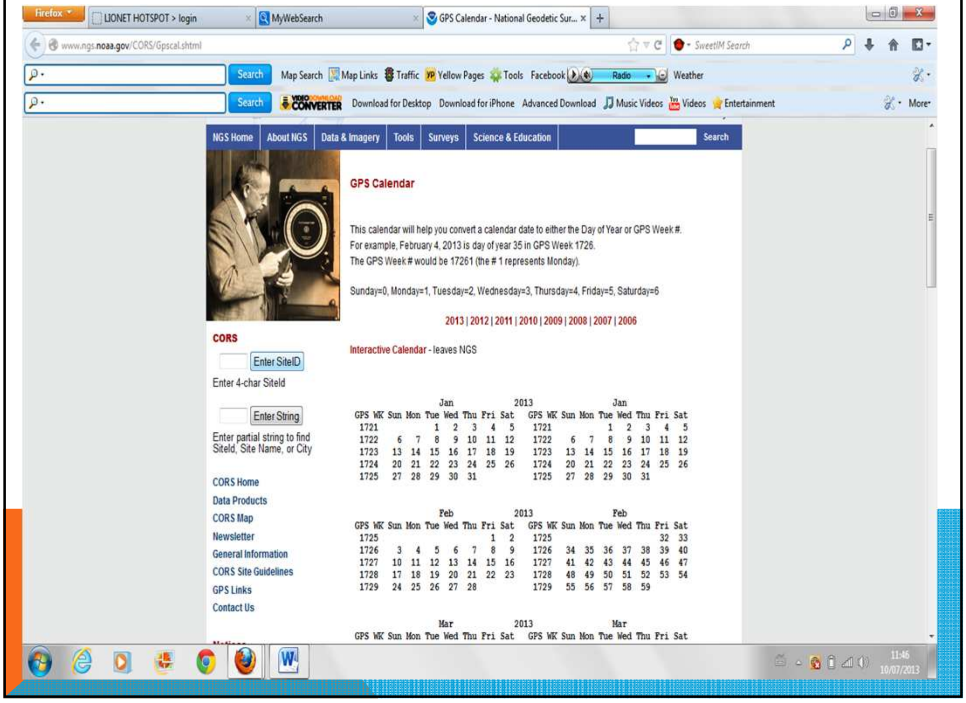
Index of /data

Name	Last modified	Size	Description
Parent Directory		-	
ORBITS/	02-Jan-2013 07:51	-	
RINEX/	02-Jan-2013 07:51	-	
logs/	10-Jul-2013 00:02	-	

Apache/2.2.16 (Ubuntu) Server at server.nignet.net Port 80

Step 1. Log on the above Website and go public data.

Step 2 go to Google and type GPS calendar, in the GPS calendar choose the date that is equivalent to the day you carry out the observation



GPS Calendar

This calendar will help you convert a calendar date to either the Day of Year or GPS Week #.
For example, February 4, 2013 is day of year 35 in GPS Week 1726.
The GPS Week # would be 17261 (the # 1 represents Monday).

Sunday=0, Monday=1, Tuesday=2, Wednesday=3, Thursday=4, Friday=5, Saturday=6

2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006

Interactive Calendar - leaves NGS

```
                    Jan                2013                Jan
GPS WK Sun Mon Tue Wed Thu Fri Sat   GPS WK Sun Mon Tue Wed Thu Fri Sat
 1721            1   2   3   4   5    1721            1   2   3   4   5
 1722    6   7   8   9  10  11  12    1722    6   7   8   9  10  11  12
 1723   13  14  15  16  17  18  19    1723   13  14  15  16  17  18  19
 1724   20  21  22  23  24  25  26    1724   20  21  22  23  24  25  26
 1725   27  28  29  30  31            1725   27  28  29  30  31

                    Feb                2013                Feb
GPS WK Sun Mon Tue Wed Thu Fri Sat   GPS WK Sun Mon Tue Wed Thu Fri Sat
 1725                        1   2    1725                       32  33
 1726    3   4   5   6   7   8   9    1726   34  35  36  37  38  39  40
 1727   10  11  12  13  14  15  16    1727   41  42  43  44  45  46  47
 1728   17  18  19  20  21  22  23    1728   48  49  50  51  52  53  54
 1729   24  25  26  27  28            1729   55  56  57  58  59

                    Mar                2013                Mar
GPS WK Sun Mon Tue Wed Thu Fri Sat   GPS WK Sun Mon Tue Wed Thu Fri Sat
```

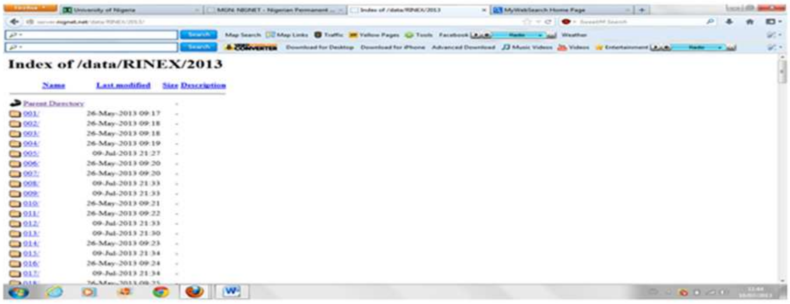
Step 3 open the public data and click on the available CORS for the day you carry out the observation.

```
Index of /data/RINEX/2013/001

      Name             Last modified      Size  Description
Parent Directory                             -
ABUZ0010.13D.Z    02-Jan-2013 06:28 761K
BKFP0010.13D.Z    02-Jan-2013 06:28 753K
CLBR0010.13D.Z    24-Jan-2013 06:43 733K
GEMB0010.13D.Z    02-Jan-2013 06:29 719K
OSGF0010.13D.Z    02-Jan-2013 06:26 769K
ULAG0010.13D.Z   26-May-2013 09:17 787K
UNEC0010.13D.Z    10-Jan-2013 06:43 787K

Apache/2.2.16 (Ubuntu) Server at server.nignet.net Port 80
```

Step 4 from the public data download the RINEX data



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Index of /data/RINEX/2013

     Name          Last modified      Size Description
Parent Directory                        -
001/          26-May-2013 09:17    -
002/          26-May-2013 09:18    -
003/          26-May-2013 09:18    -
004/          26-May-2013 09:19    -
005/           09-Jul-2013 21:27    -
006/          26-May-2013 09:20    -
007/          26-May-2013 09:20    -
008/           09-Jul-2013 21:33    -
009/           09-Jul-2013 21:33    -
010/          26-May-2013 09:21    -
011/          26-May-2013 09:22    -
012/           09-Jul-2013 21:33    -
013/           09-Jul-2013 21:30    -
014/          26-May-2013 09:23    -
015/           09-Jul-2013 21:34    -
016/          26-May-2013 09:24    -
017/           09-Jul-2013 21:34    -
```

Step 5 Unzip the RINEX data and save in the folder on your desktop

RESULTS

TABLE 1: GEODETIC COORDINATES (Φ, ƛ, h) OF THE SELECTED POINTS USED FOR OUR STUDY.

ID	Models			
	Essen and froome	Latitude	Longitude	Height
DPR773		6° 25' 25.13613" N	7° 30' 11.93661" E	236.2208 m
NIO 2		6° 25' 31.44023" N	7° 30' 13.70034" E	240.6882 m
NIO3		6° 25' 36.13396" N	7° 30' 17.49216" E	235.3279 m
	Saastamoinen			
DPR773		6° 25' 25.13610" N	7° 30' 11.93218" E	236.4558 m
NIO 2		6° 25' 31.44112" N	7° 30' 13.69752" E	240.9602 m
NIO3		6° 25' 36.13359" N	7° 30' 17.49125" E	235.6211 m
	Simplified Hopfield			
DPR773		6° 25' 25.13620" N	7° 30' 11.93757" E	236.4129 m
NIO 2		6° 25' 31.44041" N	7° 30' 13.69767" E	240.9109 m
NIO3		6° 25' 36.13333" N	7° 30' 17.49120" E	235.5757 m
	Hopfield			
DPR773		6° 25' 25.13566" N	7° 30' 11.93171" E	236.4689 m
NIO 2		6° 25' 31.44117" N	7° 30' 13.69757" E	240.9536 m
NIO3		6° 25' 36.13360" N	7° 30' 17.49132" E	235.6112 m
	No troposphere			
DPR773		6° 25' 25.13074" N	7° 30' 11.93190" E	236.7334 m
NIO 2		6° 25' 31.43726" N	7° 30' 13.68994" E	241.0860 m
NIO3		6° 25' 36.12962" N	7° 30' 17.48399" E	235.7814 m

TABLE 2: WGS 84 UTM COORDINATES OF THE SAME POINTS

ID	Models	WGS84 Coordinate		TOTAL STATION	
		EASTINGS	NORTHINGS	EASTINGS	NORTHINGS
DPR773	Essen and froome	334476.690	710278.41	334477.184	710276.911
NIO 2		334531.450	710471.894	334531.988	710470.403
NIO3		334648.383	710615.731	334648.960	710614.262
DPR773	Saastamoinen	334476.554	710278.409	334477.184	710276.911
NIO 2		334531.364	710471.922	334531.988	710470.403
NIO3		334648.355	710615.720	334648.960	710614.262
DPR773	Simplified Hopfield	334476.719	710278.412	334477.184	710276.911
NIO 2		334531.368	710471.9	334531.988	710470.403
NIO3		334648.353	710615.712	334648.960	710614.262
DPR773	Hopfield	334476.539	710278.396	334477.184	710276.911
NIO 2		334531.365	710471.923	334531.988	710470.403
NIO3		334648.357	710615.720	334648.960	710614.262
DPR773	No troposphere	334476.544	710278.244	334477.184	710276.911
NIO 2		334531.130	710471.807	334531.988	710470.403

TABLE 3: COMPARISONS OF EASTING AND NOTHING COORDINATES OBTAINED FROM GPS MODELS AND TOTAL STATION DATA (11TH NOVERMBER 2012).

Name of model	Stations	From model	From Total Station	Diff	From model	From Total Station	Diff
		ΔN	ΔN		ΔE	ΔE	
Essen &Froome	NIO3	143.837	144.187	-0.350	116.933	116.528	0.405
	DPR773	-193.484	-193.658	0.174	-54.759	-54.097	-0.662
Saastamoinen	NO3	143.778	144.187	-0.389	116.991	116.528	0.463
	DPR773	-193.513	-193.658	0.145	-54.810	-54.097	0.000
Simplified Hopfield	NIO3	143.812	144.187	-0.375	116.985	116.528	0.457
	DPR773	-193.497	-193.658	0.171	-54.649	-54.097	0.161
Hopfield	NIO3	143.377	144.187	-0.810	116.992	116.528	0.464
	DPR773	-193.948	-193.658	0.290	-54.826	-54.097	0.016
NO Troposphere	NIO3	143.794	144.187	0.607	117.002	116.528	0.474
	DPR773	-193.560	-193.658	0.098	-54.586	-54.097	-0.224

TABLE 4: COMPARISON OF EASTING AND NORTHING COORDINATES OBTAINED FROM GPS MODELS AND TOTAL STATION DATA (19TH DECEMBER 2012).

Name of model	Stations	From model	From Total Station	Diff	From model	From Total Station	Diff
		ΔN	ΔN		ΔE	ΔE	
Essen &Froome	NIO3	143.813	144.187	0.374	117.025	116.528	-0.497
	DPR773	-193.452	-193.658	0.206	-54.242	-54.097	-0.145
Saastamoinen	NO3	-143.811	144.187	0.376	116.980	116.528	-0.452
	DPR773	-193.515	-193.658	0.143	-54.597	-54.097	-0.500
Simplified Hopfield	NIO3	143.813	144.187	0.374	116.997	116.528	-0.469
	DPR773	-193.505	-193.658	0.153	-54.307	-54.097	-0.210
Hopfield	NIO3	143.810	144.187	0.377	116.985	116.528	-0.457
	DPR773	-193.516	-193.658	0.142	-54.603	-54.097	-0.506
NO Troposphere	NIO3	143.601	144.187	0.201	117.321	116.528	0.87
	DPR773	-193.100	-193.658	0.531	-53.701	-54.097	0.571

ANALYSIS OF RESULTS

To determine the amount of displacement of the beacons, the distances and bearings between the beacons were computed from both the total station data and the GPS data (for each tropospheric mode).

The coordinates of one beacons was set as zero and held fixed. The distances and bearings computed earlier were then used to compute the coordinates of the remaining two beacons.

The difference between the coordinates obtained for total station and GPS data gave the amount of displacement caused by each GPS tropospheric model. The results are shown in Tables 3, 4 and 5.

TABLE 5: DISPLACEMENTS BY THE DIFFERENT MODELS AT EACH STATION FOR THE MONTH OF NOVEMBER 2012

Model	Station	Diff
Essen and Froome	NIO3	0.204
	DPR773	0.684
Saastamoinen	NIO3	0.605
	DPR773	0.145
Simplified Hopfield	NIO3	0.591
	DPR773	0.235
Hopfield	NIO3	0.933
	DPR773	0.290
No troposphere	NIO3	0.770
	DPR773	0.844

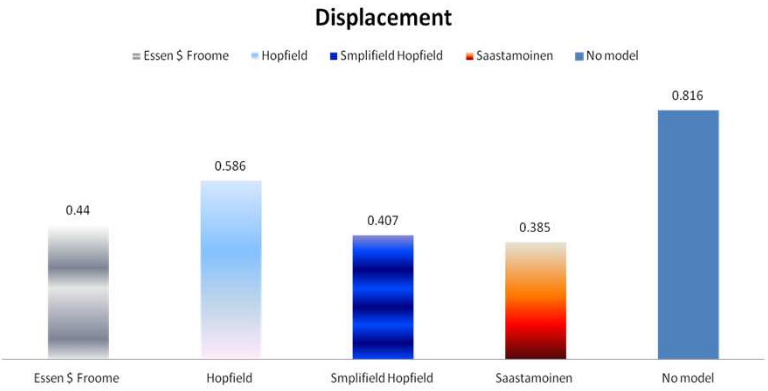
TABLE6: DISPLACEMENTS BY THE DIFFERENT MODELS AT EACH STATION FOR THE MONTH OF DECEMBER 2012

Model	Station	Diff
Essen and froome	NIO3	0.620
	DPR773	0.252
Saastamoinen	NIO3	0.588
	DPR773	0.20
Simplified Hopfield	NIO3	0.600
	DPR773	0.260
Hopfield	NIO3	0.592
	DPR773	0.526
No troposphere	NIO3	0.920
	DPR773	0.729

TABLE 7: MEAN VALUES OF THE DISPLACEMENT FOR THE TWO MONTHS OBSERVATION

Model	MEAN (m)
Essen and froome	0.44
Saastamoinen	0.385
Simplified Hopfield	0.407
Hopfield	0.586
No troposphere	0.816

THE DISPLACEMENT IS SHOWN IN THE BAR CHART BELOW.



ANALYSIS OF RESULTS CONTINUED

From the available result, we find out that:

better improvement was obtained when we applied a tropospheric model.

Saastamoinen model has a better improvement with average mean value of 0.385m compare with Simplified Hopfield model with average mean value of 0.407m.

The other models gave the average mean value of 0.44m for Essen and Froome model,0.586m for Hopfield model while NO troposphere gives 0.86m for the two month observations.

CONCLUSION AND RECOMMENDATIONS

This project has experimentally demonstrated the influence of different tropospheric models on the pillars located within University of Nigeria Enugu Campus

Tropospheric delay increases during the morning hours and decreases at sunset

The four models investigated i.e. the Saastamoinen, Hopfield, Essen and froome and Simplified Hopfield models show no significance difference in their performance.

Better improvements in the positions were achieved by the application of the different tropospheric model compared to No model i.e. No troposphere.

CONCLUSION AND RECOMMENDATION

The Saastamoinen model produced a better mitigation of the tropospheric delay, with an average improvement of 0.385m.

Better improvements on the coordinate differences were achieved by the application of the Saastamoinen model than the other models. But Simplified Hopfield model also shows a better tropospheric mitigation with average of 0.407m.Therefore, it is concluded that Saastamoinen model shows better performance in mitigating the tropospheric effect hence it is recommended for the processing of the GPS observations

THANK YOU FOR LISTENING