ANALYSIS OF THE SPATIO-TEMPORAL VARIABILITY AND IMPACT OF TROPOSPHERIC DELAY ON THE POSITIONAL ACCURACY IN GNSS PPP OBSERVATIONS

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INTRODUCTION

- Global measurement trend in GNSS positioning is gradually shifting focus from RTK to PPP (COR Stations being a major application of PPP).

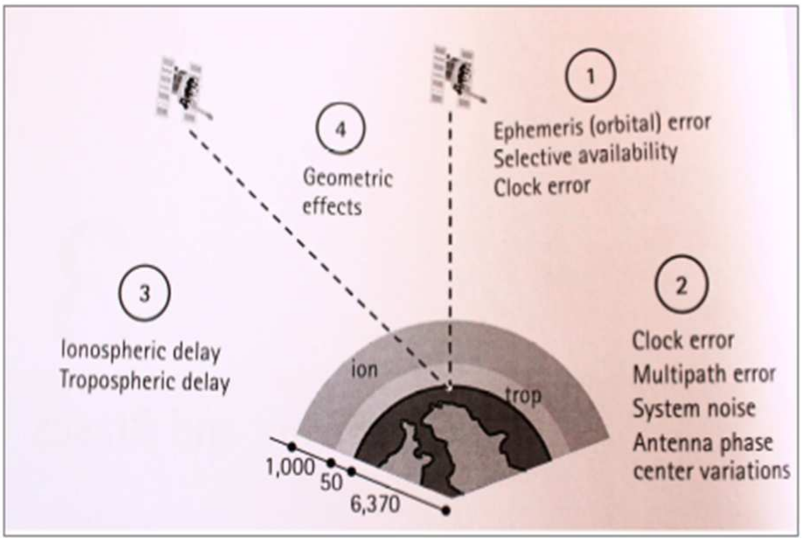
- Similar to conventional RTK positioning principles, certain error sources abound that reduce the positioning accuracy in PPP observations; chief amongst them being the troposphere.

- Earlier research on Tropospheric error Model portrays the saastomoinen model as the optimal model for tropospheric delay estimation. Şanlio Ğlu and Zeybek (2012), Maduabughichi et al., (2014)

INTRODUCTION (CONTD) / JUSTIFICATION

- Tropospheric delay depends on temperature, humidity and pressure (İsmail and Mustafa, 2012).
- It also varies with the height of receiver setup point and the type of terrain below signal path; this results in minimised tropospheric delay at the user's zenith (about 2 - 2.5m) and maximum delay at the horizon (about 20 – 28m) (Brunner and Welsh, 1993; Leick, 1995).
- Consequently, It can be inferred that the tropospheric delay should be a spatio-temporal variable with its effects differing based on temperature, humidity, pressure and Satellite to receiver distance/slant.
- This research attempts to assess the impact and spatio-temporal variability of tropospheric delay on PPP technique in GNSS observations across Nigeria

GPS errors and biases. (El-Rabbany A, 2002)



AIM OF THE RESEARCH

- The aim of this research is to assess the impact and spatio-temporal variability of tropospheric delay on PPP technique in GNSS observations across Nigeria.

OBJECTIVE OF THE RESEARCH

- 1. Study the pattern/fluctuation of the variation in tropospheric delay across the study area during the period under study.
- 2. Ascertain the suitability or otherwise of the SBAS for modeling tropospheric delay within the study area.
- 4. Identify the magnitude of positional error that is incurred at different locations across the study area at different periods.

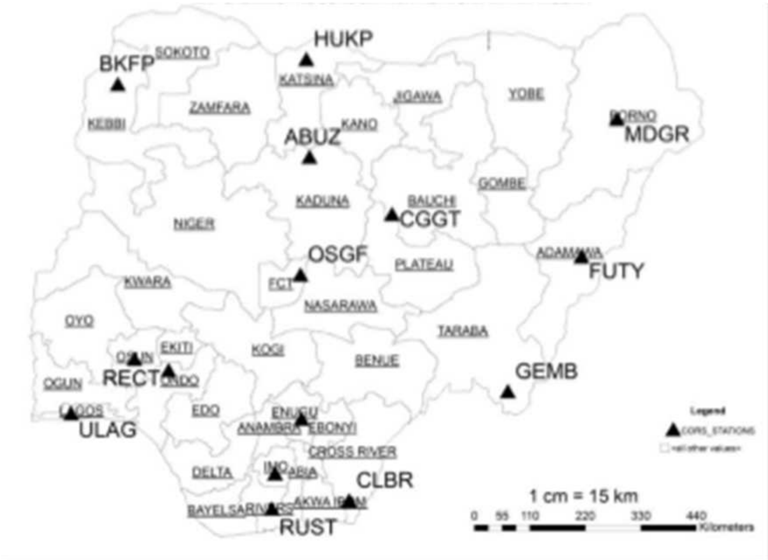
MODELS FOR TROPOSPHERIC DELAY ESTIMATION

- **SAASTEMOINEN MODEL**:
- Some earlier Literature considers this as the best model for estimating the effects of total zenith delay especially for low latitude region (Satirapod, and Chalermwattanachai, 2004, Opaluwa et al., 2013, Maduabughichi et al., 2014).
- $\Delta L = \frac{2.277*10^{-3}}{COS(90°-V)}\ [\,P_0 + \left(\frac{1255}{T_0} + 0.05\right).e_0 - 1.16.tan^2(90° - V)]$
- Where:
- $\Delta L = Zenith\ Total\ Delay$
- $P_0 = Surface\ Pressure$ in mbar
- $T_0 = Surface\ Temperature\ in\ degrees\ Kelvin$
- $e_0 = Partial\ Water\ surface\ pressure\ in\ mbar$
- ZTD = ZHD + ZWD
- Where ZTD = Zenith Total Delay
- ZHD = Zenith Hydrostatic Delay
- ZWD = Zenith Wet Delay

MODELS FOR TROPOSPHERIC DELAY ESTIMATION (CONTD)

- **Satellite Based Augumented System (SBAS)**:
- These are a set of satellite based solutions that are made available by the IGS.
- The IGS products are downloaded from the IGS website for the specific GPS day of the year of observation.
- Tropospheric corrections come with ".trp" extension.

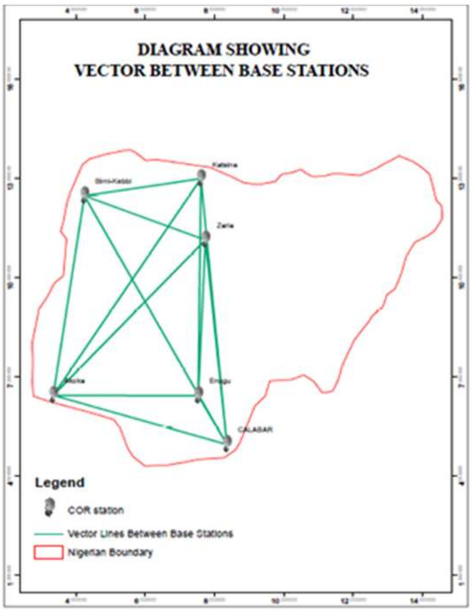
THE NIGERIAN CORS NETWORK (Nwilo, et al 2013)



DATA USED

- 24 hours data was collected from six (6) CORS across Nigeria at three months interval beginning at 1st of January, 2014 to 1st of June 2014 from Nignet website (www.nignet.net).
- Also, the IGS corrections for troposphere were obtained from the IGS website (www.igscb.jpl.nasa.gov/components/data.html)
- Due to Non-broadcast of data by some of the COR Stations during the study period, only 6 of the CORS were selected and used.

STUDY AREA



METHODOLOGY

- The rtkLib software was used for the analysis. The analysis was done in PPP static mode with result output options selected in Eastings, Northings and Up format.
- Owing to the prevalence of multipath activities at the lower elevation angle (e.g 0 - 10˚) and the limited availability of GNSS satellite for observation at higher elevation (e,g. above 20˚), data analysis for this study was performed utilising 15˚elevation mask angle. The essence of this is to minimise the accumulation of errors from other sources in the solution since the goal is to assess the effects of tropospheric delay on the PPP solution.

RESULTS

Summarised table showing Estimate of the monthly average of the positional effect (expressed in metres) of tropospheric delay (Table 1)

ANALYSIS OF SPATIO - TEMPORAL VARIATION OF AVERAGE VALUE OF POSITIONAL ERROR DUE TO TROPOSPHERIC DELAY ACROSS NIGERIA																			
MONTH		JANUARY						APRIL						JULY					
STATION	LOCATION	EASTING		NORTHING		HEIGHT		EASTING		NORTHING		HEIGHT		EASTING		NORTHING		HEIGHT	
		SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN
ABUZ	Kaduna	0.04	1.077	0.27	-7.136	0.058	1.579	-0.307	-0.321	2.228	2.319	-0.49	-0.508	-0.9	-0.937	6.721	6.985	-1.452	-1.503
BKFP	Kebbi	-0.66	0.687	7.287	7.612	-1.82	-1.899	-0.518	-0.546	6.875	7.171	-1.656	-1.726	-0.578	-0.604	7.121	7.44	-1.72	-1.796
CLBR	Cross Rivers	-1.291	-1.349	8.085	8.459	-0.834	-0.872	-1.109	-1.161	7.234	7.577	-0.691	-0.723	-7.294	-7.64	-1.039	-1.089	-0.759	-0.793
HUKP	Katsina	-6.935	-7.221	-1.038	-1.08	-1.808	-1.88	-0.854	-0.895	6.411	6.686	-1.609	-1.67	-0.893	-0.93	6.857	7.137	-1.717	-1.786
ULAG	Lagos	-8.306	-8.685	-0.701	-0.729	-1.195	-1.248	-0.533	-0.554	7.542	7.899	-1.001	-1.045	-7.586	-7.944	-0.503	-0.528	-0.998	-1.045
UNEC	Enugu	-7.645	-7.98	-1.098	-1.146	-0.994	-1.037	-0.907	-0.949	6.889	7.203	-0.867	-0.906	-7.276	-7.599	-0.947	-0.991	-0.972	-1.013

RESULTS (CONTD)

Table Showing Monthly average of variation in tropospheric delay across Nigeria in January, 2014 (Table 2)

MONTH	JANUARY					
STATION	EASTING (m)		NORTHING (m)		UP (m)	
	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN
ABUZ	0.04	1.077	0.27	-7.136	0.058	1.579
BKFP	-0.66	0.687	7.287	7.612	-1.82	-1.899
CLBR	-1.291	-1.349	8.085	8.459	-0.834	-0.872
HUKP	-6.935	-7.221	-1.038	-1.08	-1.808	-1.88
ULAG	-8.306	-8.685	-0.701	-0.729	-1.195	-1.248
UNEC	-7.645	-7.98	-1.098	-1.146	-0.994	-1.037

RESULTS (CONTD)

Table Showing Monthly average of variation in tropospheric delay across Nigeria in April, 2014 (Table 3)

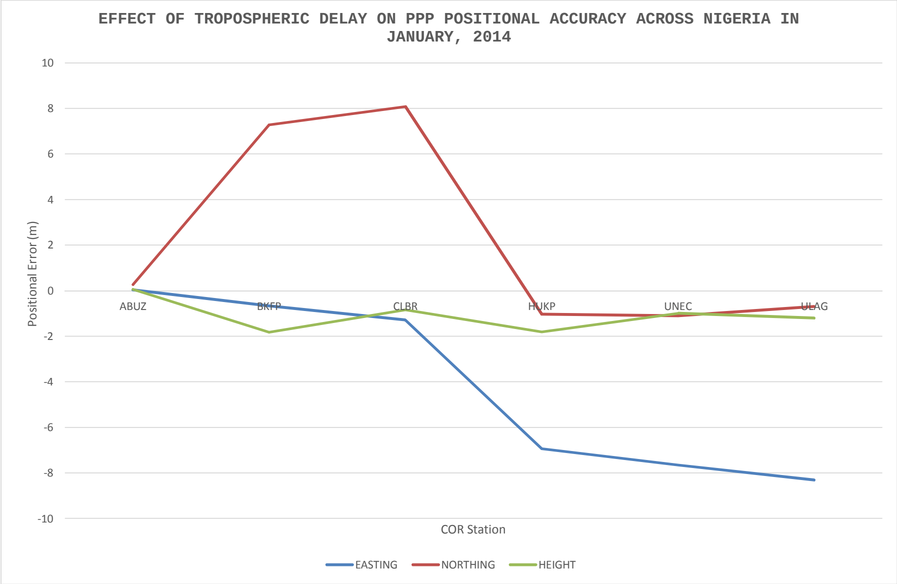
MONTH	APRIL					
STATION	EASTING (m)		NORTHING (m)		UP (m)	
	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN
ABUZ	-0.307	-0.321	2.228	2.319	-0.49	-0.508
BKFP	-0.518	-0.546	6.875	7.171	-1.656	-1.726
CLBR	-1.109	-1.161	7.234	7.577	-0.691	-0.723
HUKP	-0.854	-0.895	6.411	6.686	-1.609	-1.67
ULAG	-0.533	-0.554	7.542	7.899	-1.001	-1.045
UNEC	-0.907	-0.949	6.889	7.203	-0.867	-0.906

RESULTS (CONTD)

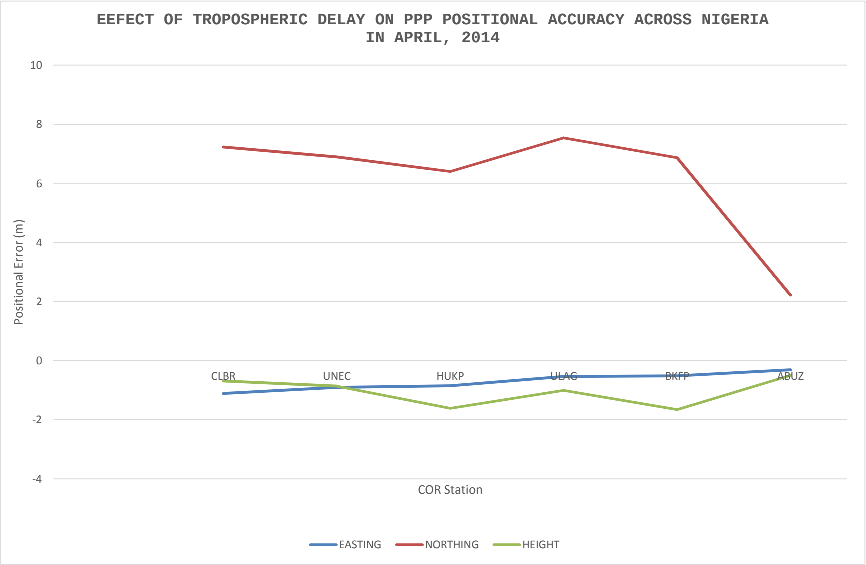
Table Showing Monthly average of variation in tropospheric delay across Nigeria in July, 2014 (Table 4)

MONTH	JULY					
STATION	EASTING (m)		NORTHING (m)		UP (m)	
	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN	SAAS-UN	SBAS-UN
ABUZ	-0.9	-0.937	6.721	6.985	-1.452	-1.503
BKFP	-0.578	-0.604	7.121	7.44	-1.72	-1.796
CLBR	-7.294	-7.64	-1.039	-1.089	-0.759	-0.793
HUKP	-0.893	-0.93	6.857	7.137	-1.717	-1.786
ULAG	-7.586	-7.944	-0.503	-0.528	-0.998	-1.045
UNEC	-7.276	-7.599	-0.947	-0.991	-0.972	-1.013

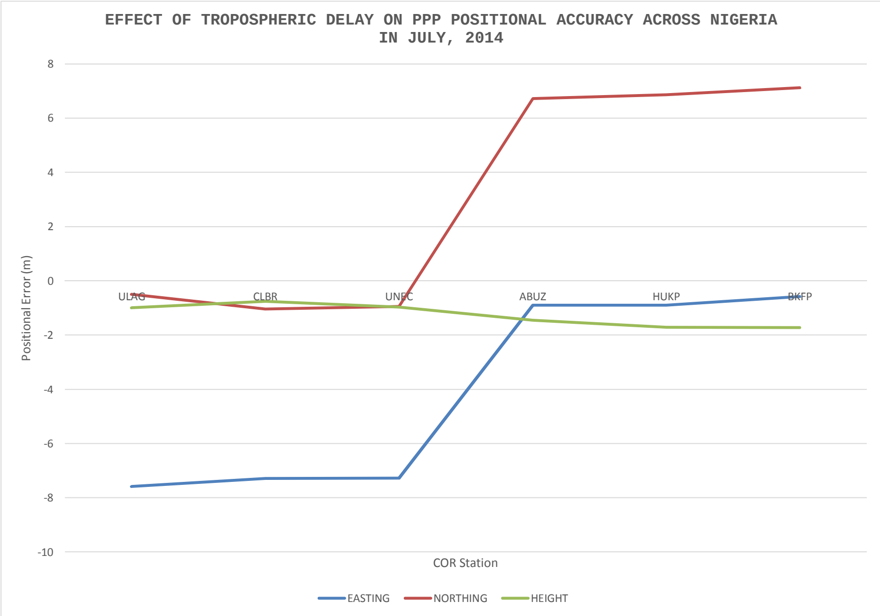
RESULTS (CONTD) (Figure 1)



RESULTS (CONTD) (Figure 2)



RESULTS (CONTD) (Figure 3)



RESULTS (CONTD) (Table 5)

MAGNITUDE OF TROPOSPHERIC ERROR ACROSS THE STUDY AREA			
STATION	JANUARY	APRIL	JULY
ABUZ	0.279m	2.302m	6.935m
BKFP	7.540m	7.091m	7.349m
CLBR	8.230m	7.351m	7.407m
HUKP	7.242m	6.665m	7.125m
ULAG	8.421m	7.627m	7.668m
UNEC	7.787m	7.002m	7.401m

RESULTS (CONTD) (Table 6)

STATISTICS OF DIFFERENCES BETWEEN SAAS AND SBAS	
ROOT MEAN SQUARE ERROR (RMS)	0.512
AVERAGE	0.064
STANDARD DEVIATION	0.193
MAXIMUM DIFFERENCE	0.279
MINIMUM DIFFERENCE	0.033

DISCUSSION OF RESULTS

1. The tropospheric delay has greater impact on the North than on the East and Up co-ordinates within the study area (Tables 1 – 4).

- This result however appears to CONTRADICT the popular notions (in conventional RTK Observations) that the positional impact of the tropospheric delay is more on the UP than on the East and North Direction.
- Hence, there is need to investigate the presence of other error sources such as station-dependent or environmental dependent errors.

DISCUSSION OF RESULTS (CONTD)

2. Through-out the period under study, ABUZ located in the North-central part of Nigeria experienced the LEAST POSITIONAL ERROR DUE TO TROPOSPHERIC DELAY.

This suggests that the North-central regions of the country have least tendencies of troposphere based errors in positioning than other parts of the country.

- This was not unexpected because the north generally has drier atmosphere than the south. However, further research may be conducted by analysing data over a longer period

DISCUSSION OF RESULTS (CONTD)

3. Consequently, as further verified from Table 5, tropospheric delay is more in wet atmosphere than in dry atmosphere.

Tropospheric delay affects positional accuracy of GNSS observations more in the wet season than in the dry season i.e drier air have least tropospheric delay than wet air.

DISCUSSION OF RESULTS (CONTD)

4. The spatio-temporal pattern of variability of the delay however appears to be "LEAP FROG" in nature.

Least delay is found predominantly in the (ABUZ) North-Central region probably due to the dry nature of the atmosphere

The stations within the South- South and South-west have Larger delays. **Proximity to the equator could be a factor due to presence of high water vapour.**

Anomalous spikes were found in BKFP and HUKP (North west). **Un-identified uncertainty may be present, needs further assessment.**

DISCUSSION OF RESULTS (CONTD)

5. Using Saastimoinen model as the Control, the significance of using the SBAS solutions for correcting tropospheric error in GNSS PPP observations for centimetre level accuracy positioning was statistically justified (Table 6).

CONCLUSION

- Impact of spatio-temporal variability of tropospheric delay on GNSS PPP solution in Nigeria has been studied. Effects on positional accuracy was found to be more during the wet season than in the dry season and also more in the south than in north. Further study is desired to isolate the causes of the uncertainty identified in the results.
- This may involved long term assessment of the tropospheric pattern and effects on positioning as well as exploring the use of a GNSS scientific software (such as the Bernese) to aid conclusive inferences on:

(a) The near-mirror trend of spatial variation in the error observed in the East and North respectively.

(b) The North having greater troposphere based error than the Up

(c) Consistence in the pattern of variation in the Up coordinates.

(d) The Spike in Tropospheric delay at the North-West Stations

THANK YOU FOR LISTENING