Performance and prospects of Low-cost Global Navigation Satellite Systems Receiver in measurements of ionospheric total electron content within equatorial anomaly region in Africa

Babatunde Rabiu, *Daniel Okoh, Aderonke Obafaye, Gopi Seemala, Anton Kashcheyev, Bruno Nava*

Beacon Satellite Symposium August, 2022

Co-authors

Babatunde Rabiu, Aderonke Obafaye, Daniel Okoh, Kemi Dare-Idowu

Centre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria

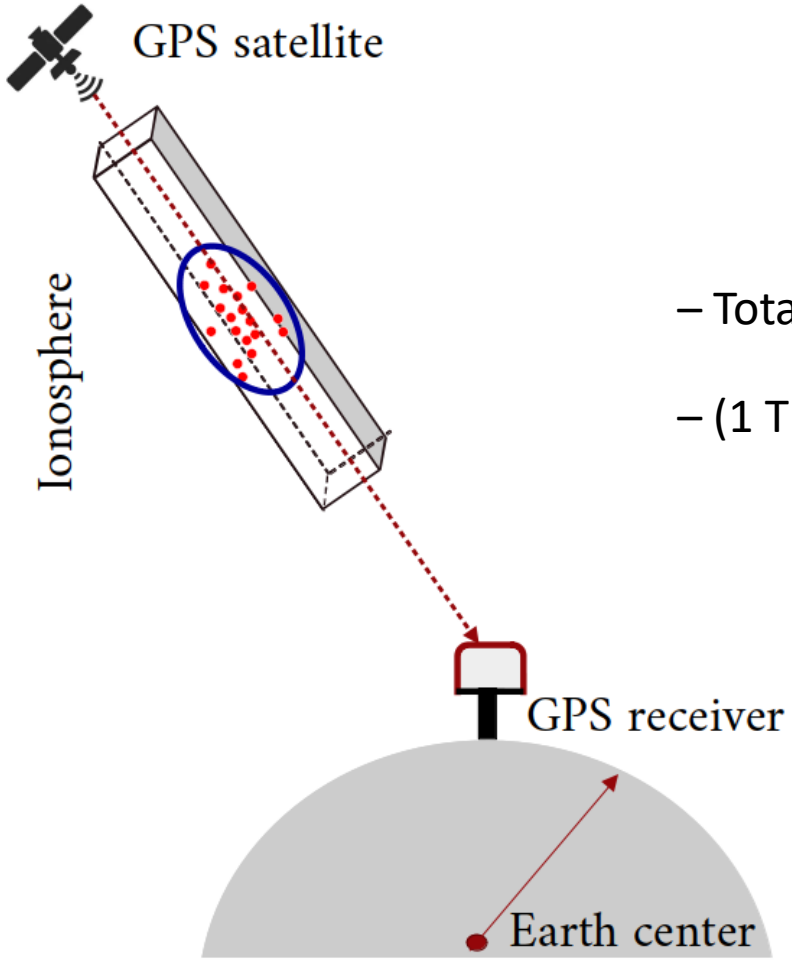
Institute for Space Science and Engineering, African University of Science and Technology, Abuja, Nigeria

Gopi Seemala - Indian Institute of Geomagnetism, Navi Mumbai, India

Anton Kashcheyev, - University of New Brunswick, Fredericton, Canada

Bruno Nava - The Abdus Salam International Centre for Theoretical Physics (ICTP) STI, Trieste, Italy

What is the Total Electron Content?

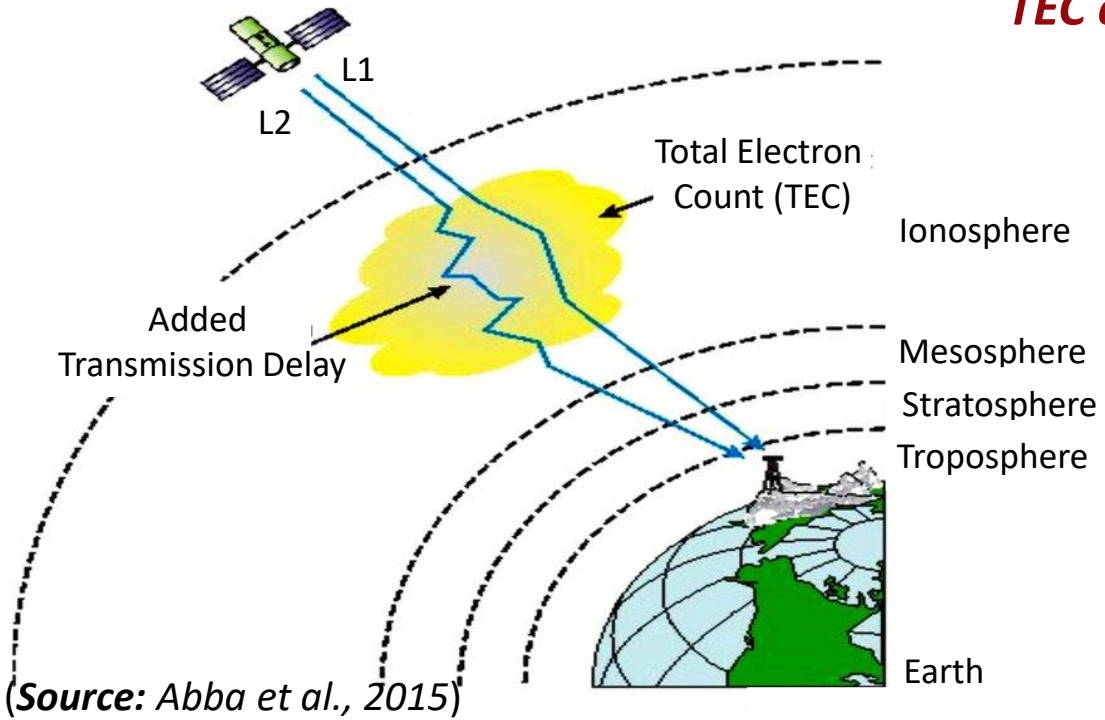


– Total number of electrons in a pathline

– (1 TECU = 1 x 10^16 electrons/m2)

Why the interest in TEC?

TEC effect must be eliminated!



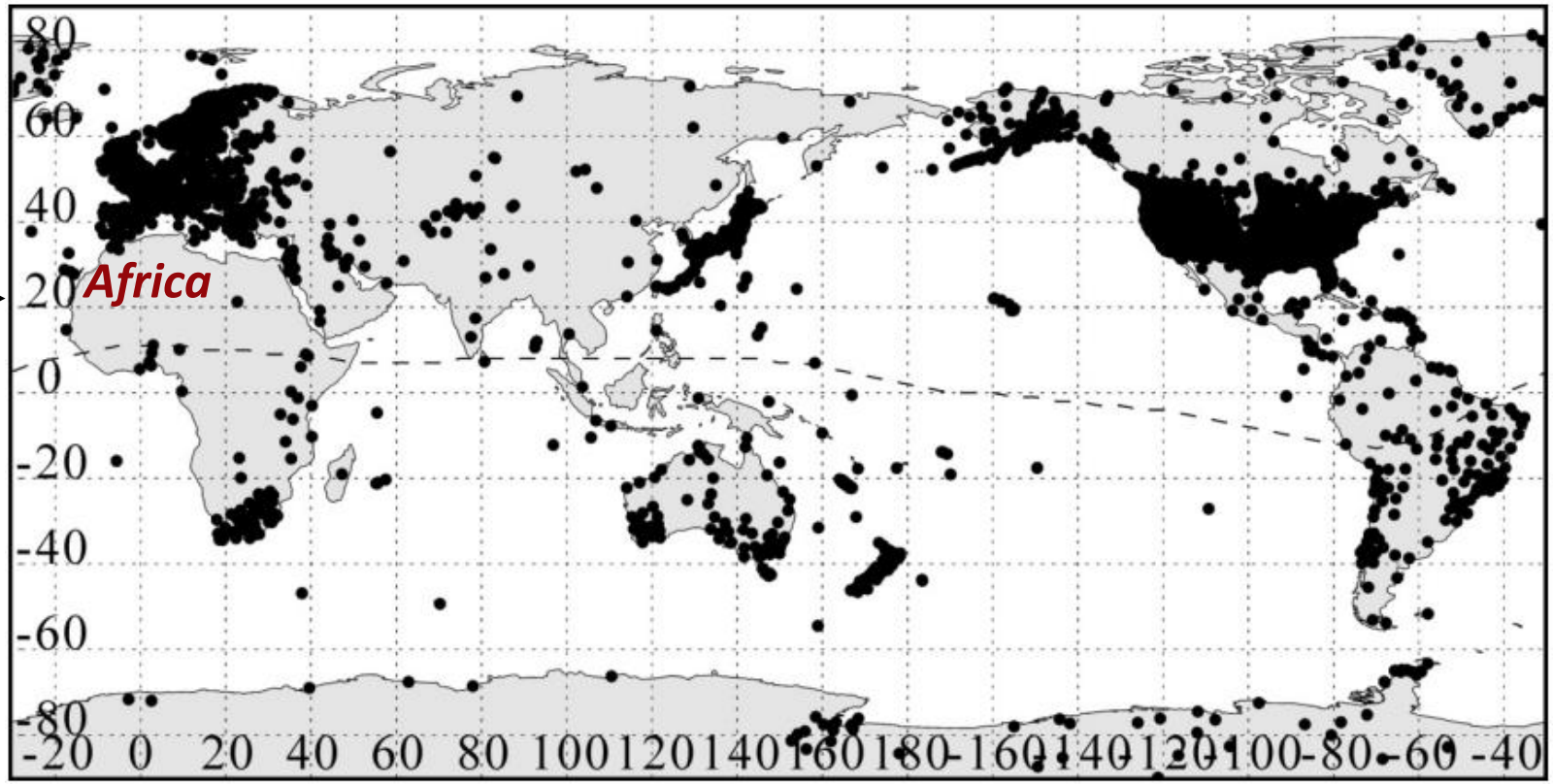
(***Source:*** *Abba et al., 2015*)

(1) Affects radio wave propagation- Signal delay (1m – 100 m).

(2) Transmission delay of signals.

Distribution of GNSS receivers

Data paucity



(***Source:*** *Tsugawa et al., 2012*)

Scientific Questions

High-cost Septentrio

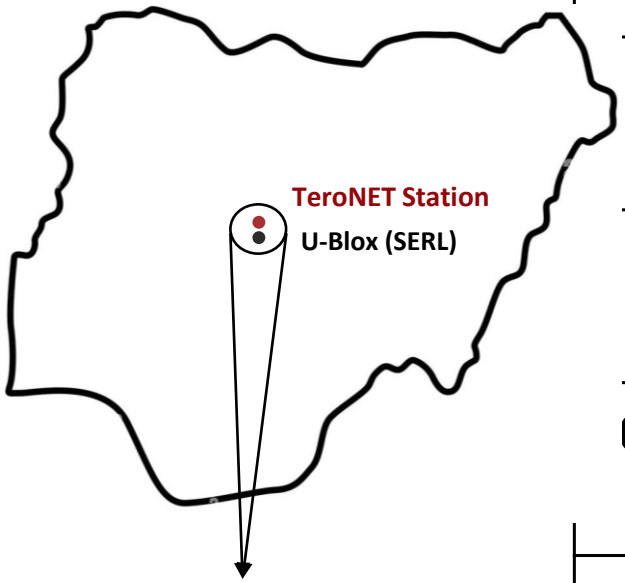
$20,000

Low-cost U-Blox

$1,000

- Does the U-BLOX TEC compare well with the high-cost geodetic TEC ?
- How well does U-BLOX TEC agree with estimates from AfriTEC and NeQuick ?

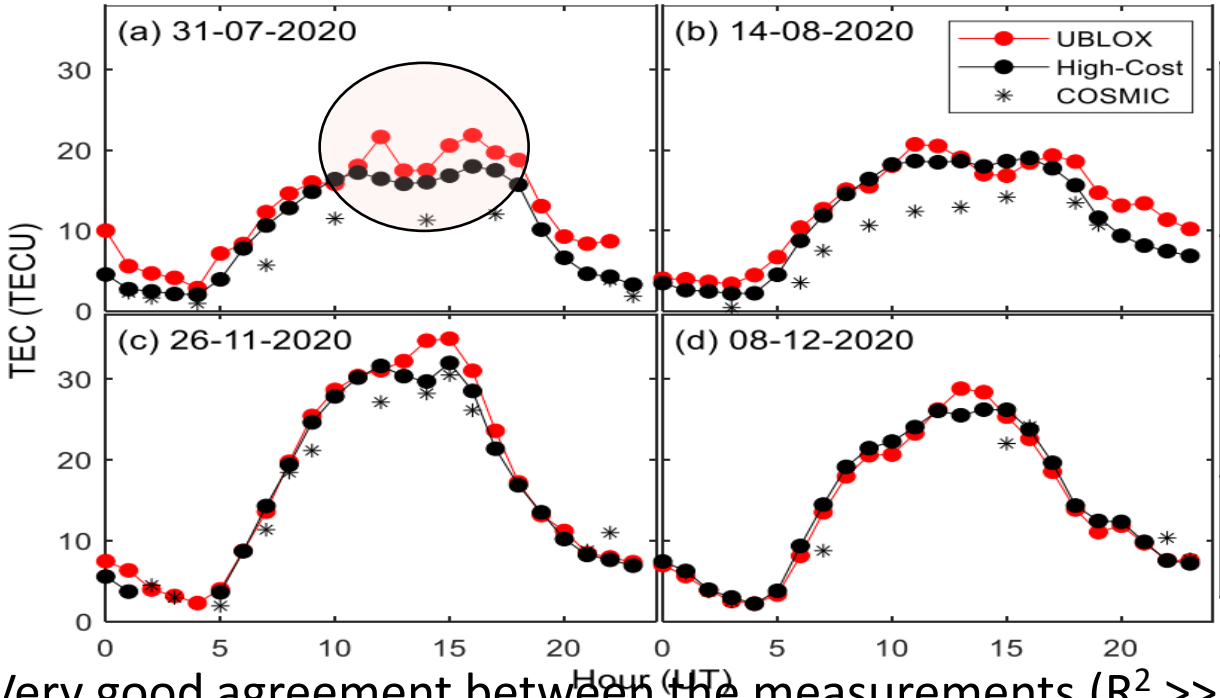
Study Station, Data sets, and Methods



Data*: July - August and November – December, 2020*

Data Sources	References
TEC: U-Blox F9P receiver	
GPS data: TeroNet station	https://teronet.nignet.net/
GPS TEC: COSMIC-2	https://data.cosmic.ucar.edu/
AfriTEC model	https://carnasrda.com/tec-models/
NeQuick model	T/ICT4D ICTP, Trieste, Italy

Diurnal comparison of TEC from U-Blox, high-cost receiver and COSMIC RO

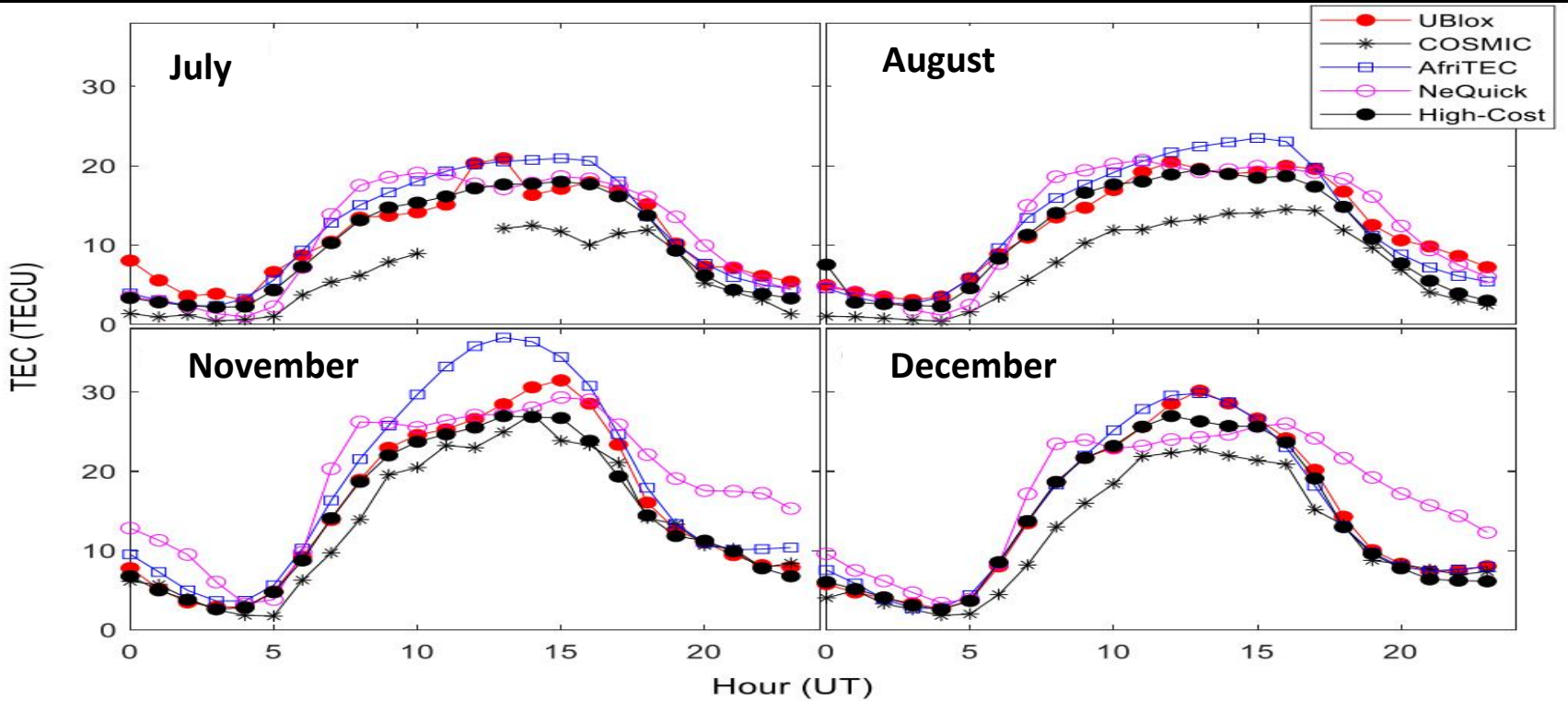


'All Data Points'

	U-Blox vs HCR	U-Blox vs COSMIC
R^2	0.88	0.85
m	0.96	1.06
c	1.03	2.74

- ✓ Very good agreement between the measurements (R^2 >> 0.8) and similar dynamics.
- ✓ Slight discrepancies in U-Blox TEC due to antenna limitation.
- ✓ On average, COSMIC TEC were the lowest because of the height of integration.

Monthly averages of the TEC daily profiles



- High correlation (>> 0.9) between U-Blox-TEC and other TEC sources.
- RMSD was persistently lower than 5 TECU.
- AfriTEC recorded the best agreement, while R is lowest in July.

Statistical metrics between U-Blox TEC and TEC values from other four sources

	Correlation coefficient				Root Mean Square Deviation			
	High-cost	**AfriTEC**	NeQuick	COSMIC	High-cost	AfriTEC	NeQuick	COSMIC
Jul	0.97	**0.96**	0.92	0.93	1.95	2.31	2.88	**5.00**
Aug	0.96	**0.98**	0.96	0.98	2.07	2.12	2.25	4.98
Nov	0.99	**0.99**	0.94	0.98	1.90	3.77	4.83	3.10
Dec	0.99	**0.99**	**0.90**	0.99	1.24	**1.00**	4.65	3.83
Mean	0.978	**0.980**	0.930	0.970	1.79	**2.30**	3.65	4.23

(1) Best correlation between AfriTEC and U-Blox (R^2 = 0.98).

(2) RMSD between AfriTEC and U-Blox was the second lowest*.

(3) Overall, estimates of NeQuick compared poorly with U-Blox TEC.

Available online at www.sciencedirect.com

ScienceDirect

Advances in Space Research 68 (2021) 3835–3845

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

www.elsevier.com/locate/asr

New results of ionospheric total electron content measurements from a low-cost global navigation satellite system receiver and comparisons with other data sources

Daniel Okoh [a,b,*], Aderonke Obafaye [a], Babatunde Rabiu [a,b], Gopi Seemala [c], Anton Kashcheyev [d], Bruno Nava [e]

[a] Centre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria
[b] Institute for Space Science and Engineering, African University of Science and Technology, Abuja, Nigeria
[c] Indian Institute of Geomagnetism, Navi Mumbai, India
[d] University of New Brunswick, Fredericton, Canada
[e] The Abdus Salam International Centre for Theoretical Physics (ICTP) T/ICT4D, Trieste, Italy

Received 23 January 2021; received in revised form 16 June 2021; accepted 12 July 2021
Available online 21 July 2021

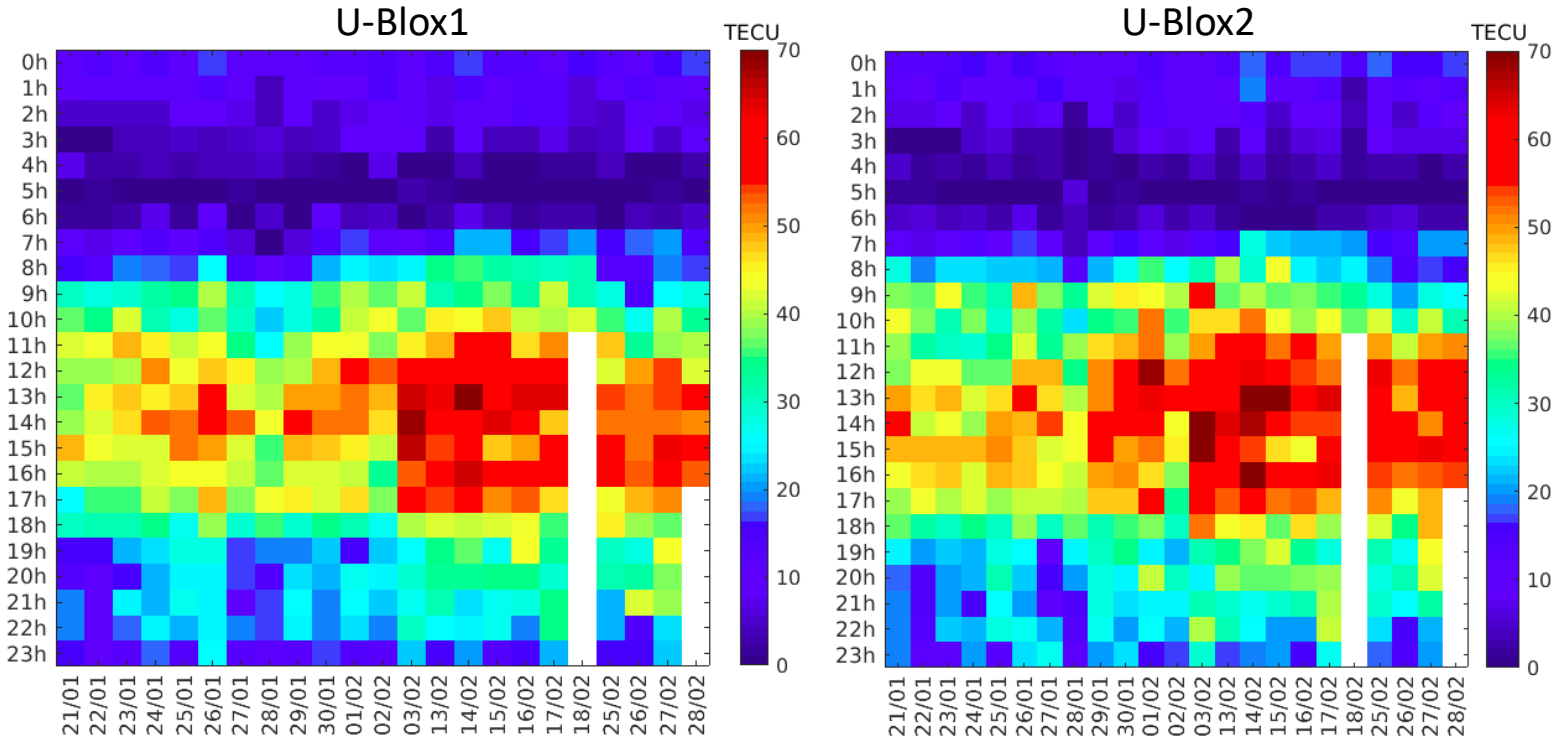
Comparative study between two different but co-located antennas

Antenna of U-Blox1

Antenna of U-Blox2

NB: Model of U-Blox receiver is the same!

TEC Variability between two co-located antennas (*Jan-Feb, 2022*)



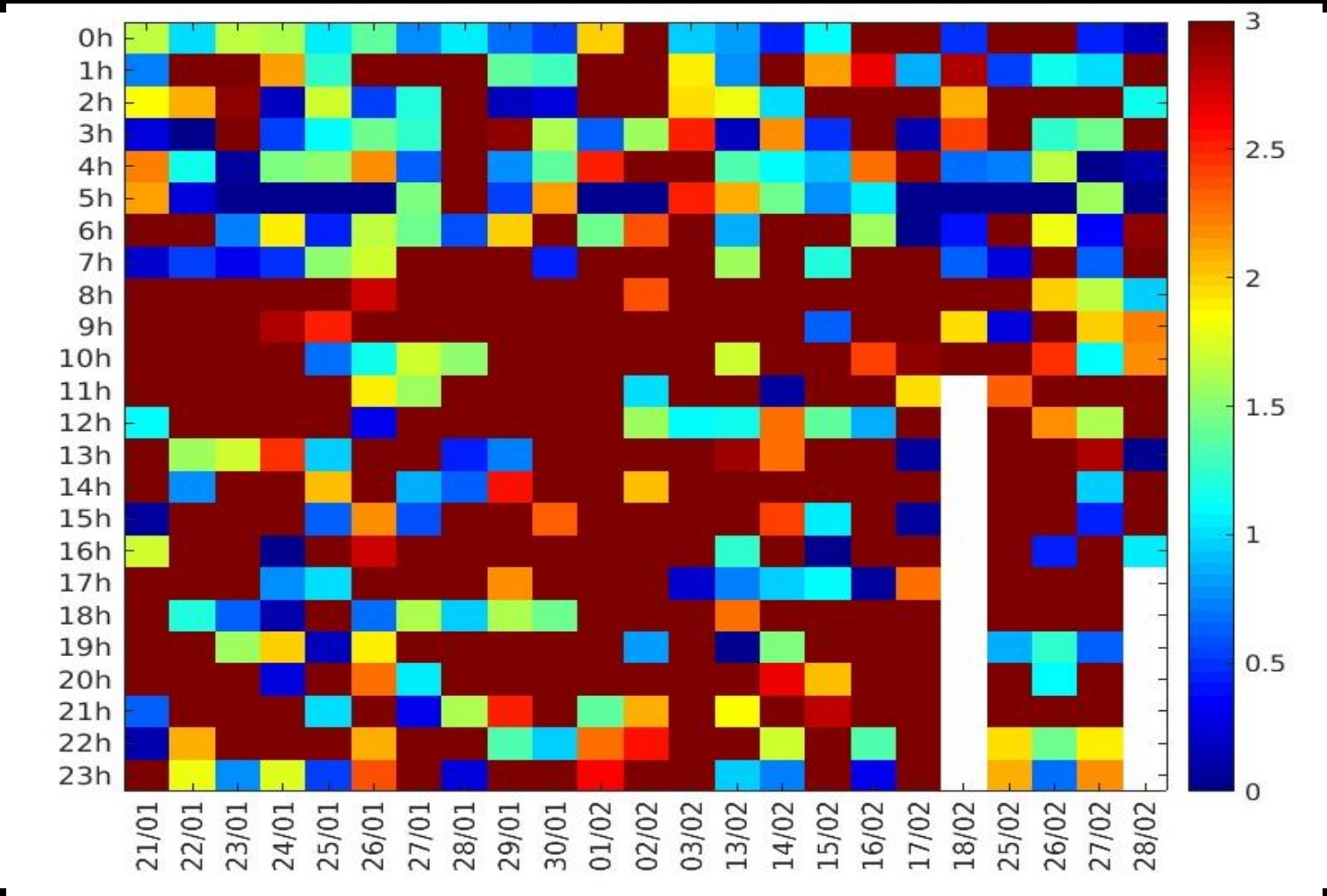
(1) Data from both systems are comparable: $0 \geq TEC \leq 70$.

(2) TEC exhibit a large temporal gradient: peaks around noon.

(3) Highest TEC is obtained in the February

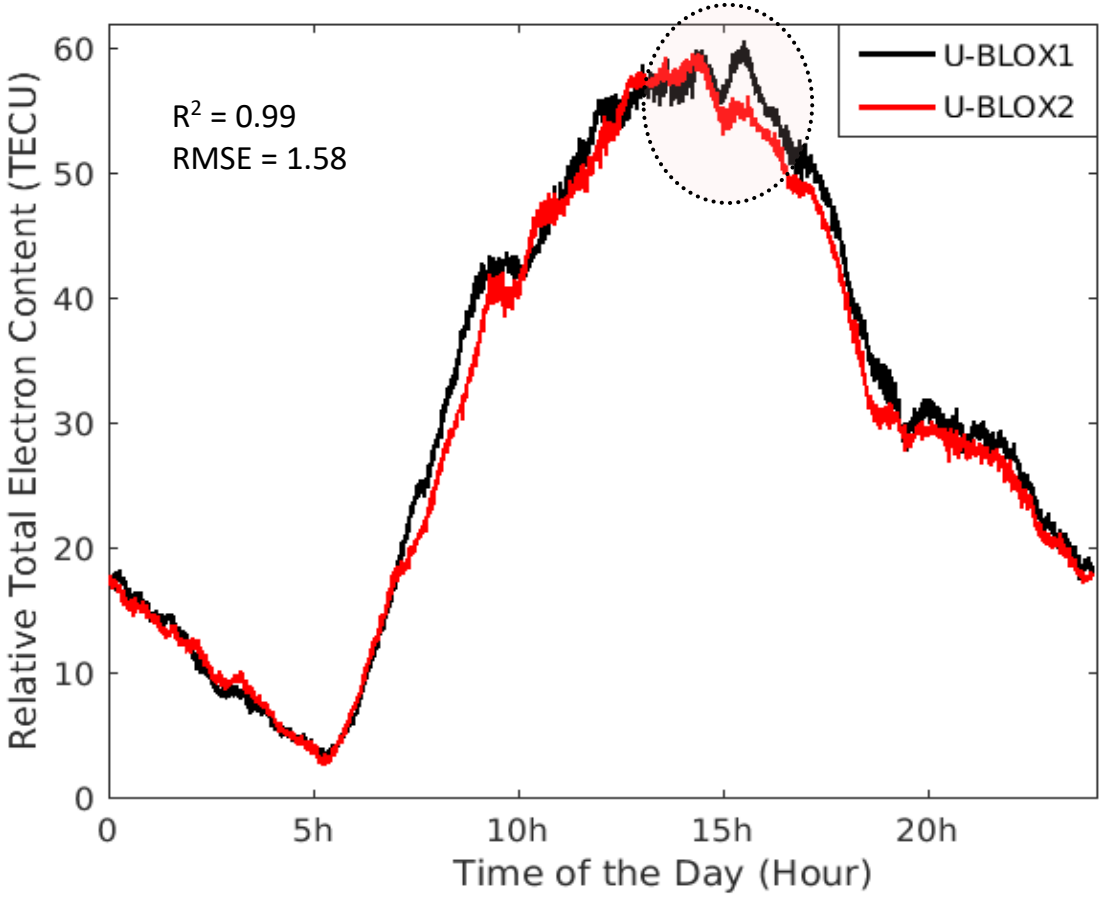
Absolute TEC difference from 2 co-located antennas

permissible Mean difference < 3 TECU



Diurnal variation of relative TEC

- ✓ Both measurements are very comparable with $R^2 > 0.9$.
- ✓ Slight discrepancies during the postnoon period.



Conclusions

- ✓ U-Blox perform so well like high cost receiver in capturing the dynamics of the ionosphere
- ✓ U-Blox TEC correlated well with TEC from high-cost GNSS receiver and COSMIC ($R > 0.9$).
- ✓ RMSDs between the U-Blox TEC and the models estimates are less than 5 TECU.
- ✓ Very good agreement between the TEC from the different antennas of the co-located receivers.

Thank You

Perspectives

- Elimination of multi-path induced noise from U-Blox TEC data.
- Strategic deployment of U-Blox in Nigeria (CAR-GNSS initiative).
- CAR-NASRDA is ready to collaborate on:
  - Data acquisition
  - Modeling
  - Research
- Re-evaluation of NigTEC/AfriTEC model using newly acquired TEC from the U-Blox.

Performance and prospects of Low-cost Global Navigation Satellite Systems Receiver in measurements of ionospheric total electron content within equatorial anomaly region in Africa

Babatunde Rabiu, *Daniel Okoh, Aderonke Obafaye, Gopi Seemala, Anton Kashcheyev, Bruno Nava*

Center for Atmospheric Research-National Space Research and Development Agency, Anyigba, Abuja, Nigeria

Beacon Satellite Symposium August, 2022