Performance and prospects of low-cost Global Navigation Satellite System receivers in monitoring space weather at African low latitudes

[1,2]**Babatunde Rabiu,** [1]*Daniel Okoh,* [1]*Aderonke Obafaye,* [1]*Oluwakemi Dare-Idowu,* [3]*Gopi Seemala,* [4]*Anton Kashcheyev,* [5]*Bruno Nava*

[1]African Regional Centre for Space Science and Technology Education-English-National Space Research and Development Agency, Abuja.
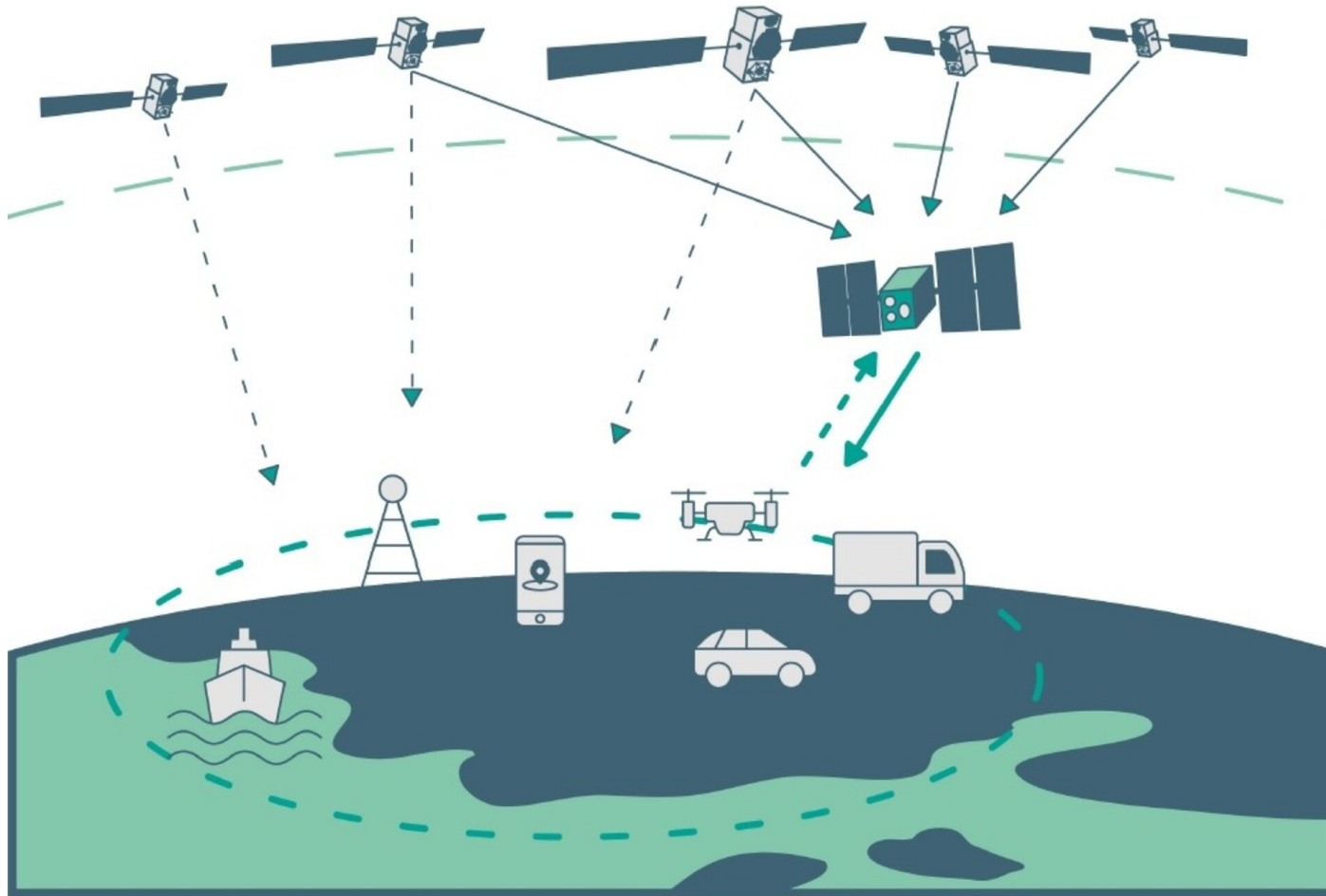
[2]Institute for Space Science and Engineering, African University of Science and Technology, Abuja, Nigeria

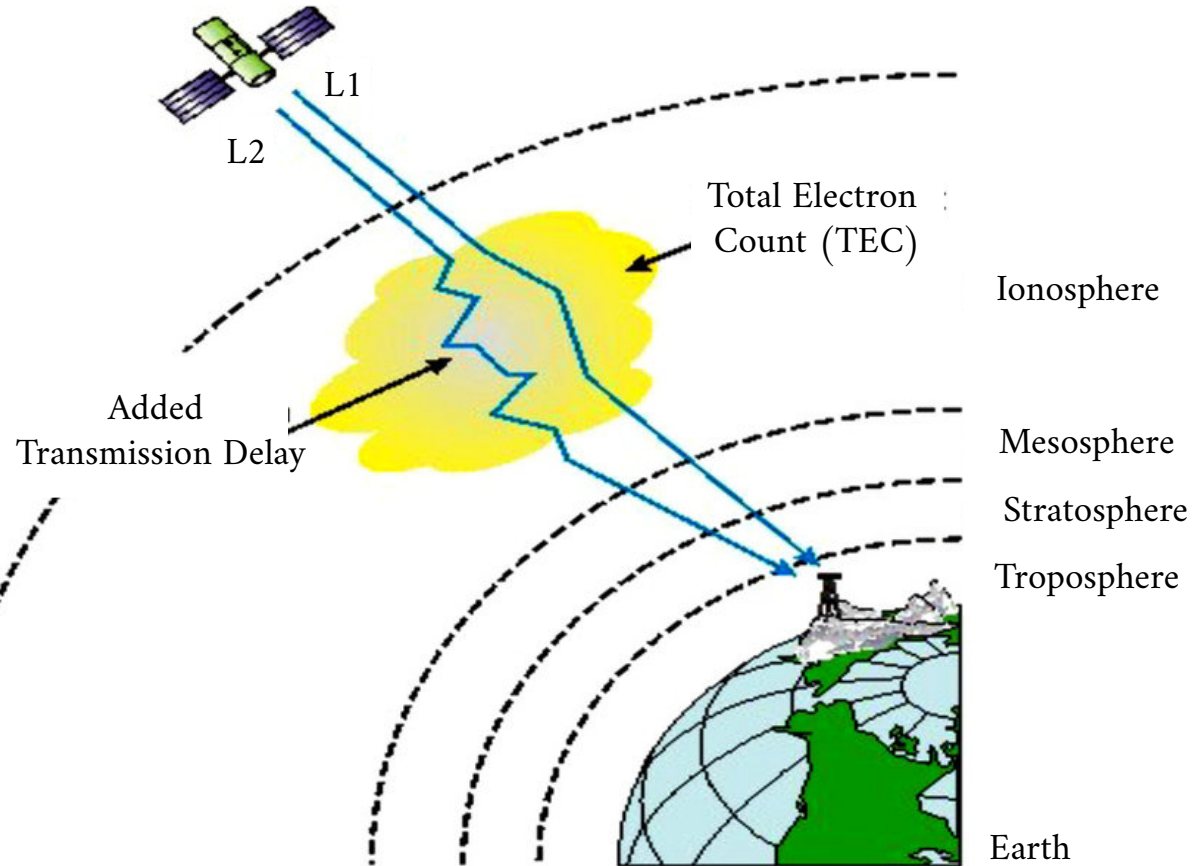[3]Indian Institute of Geomagnetism, Navi Mumbai, India

[4]University of New Brunswick, Fredericton, Canada

[5]The Abdus Salam International Centre for Theoretical Physics (ICTP) STI, Trieste, Italy
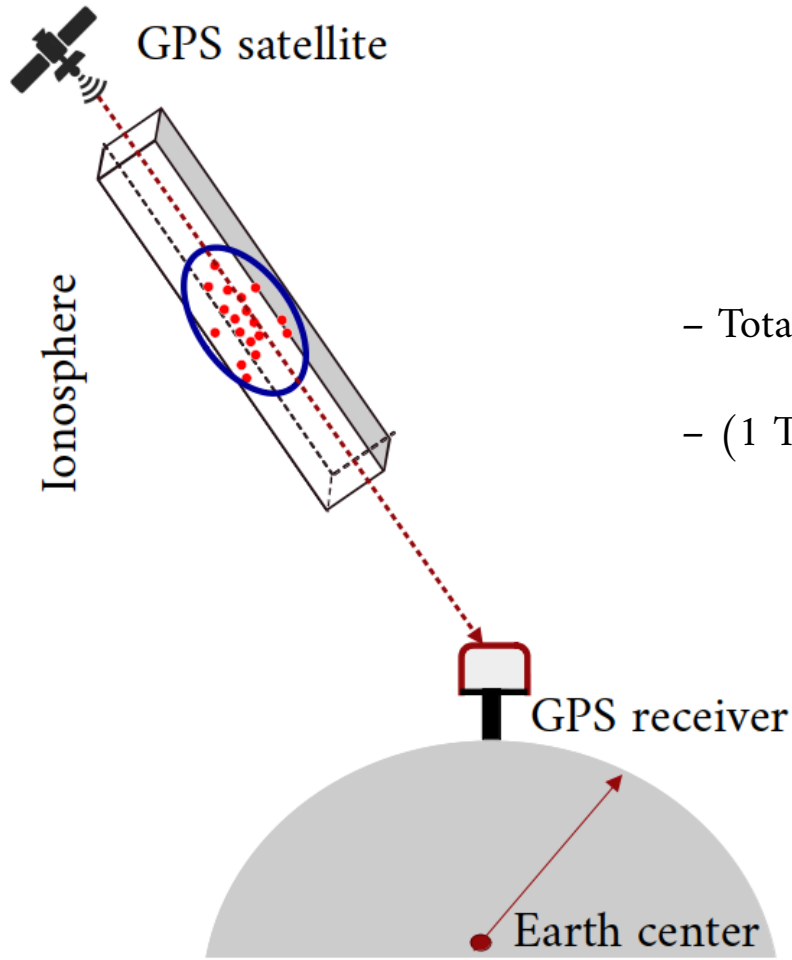
Why GNSS matters?

Why the interest in TEC?

L1

L2

Total Electron Count (TEC)

Ionosphere

Added Transmission Delay

Mesosphere

Stratosphere

Troposphere

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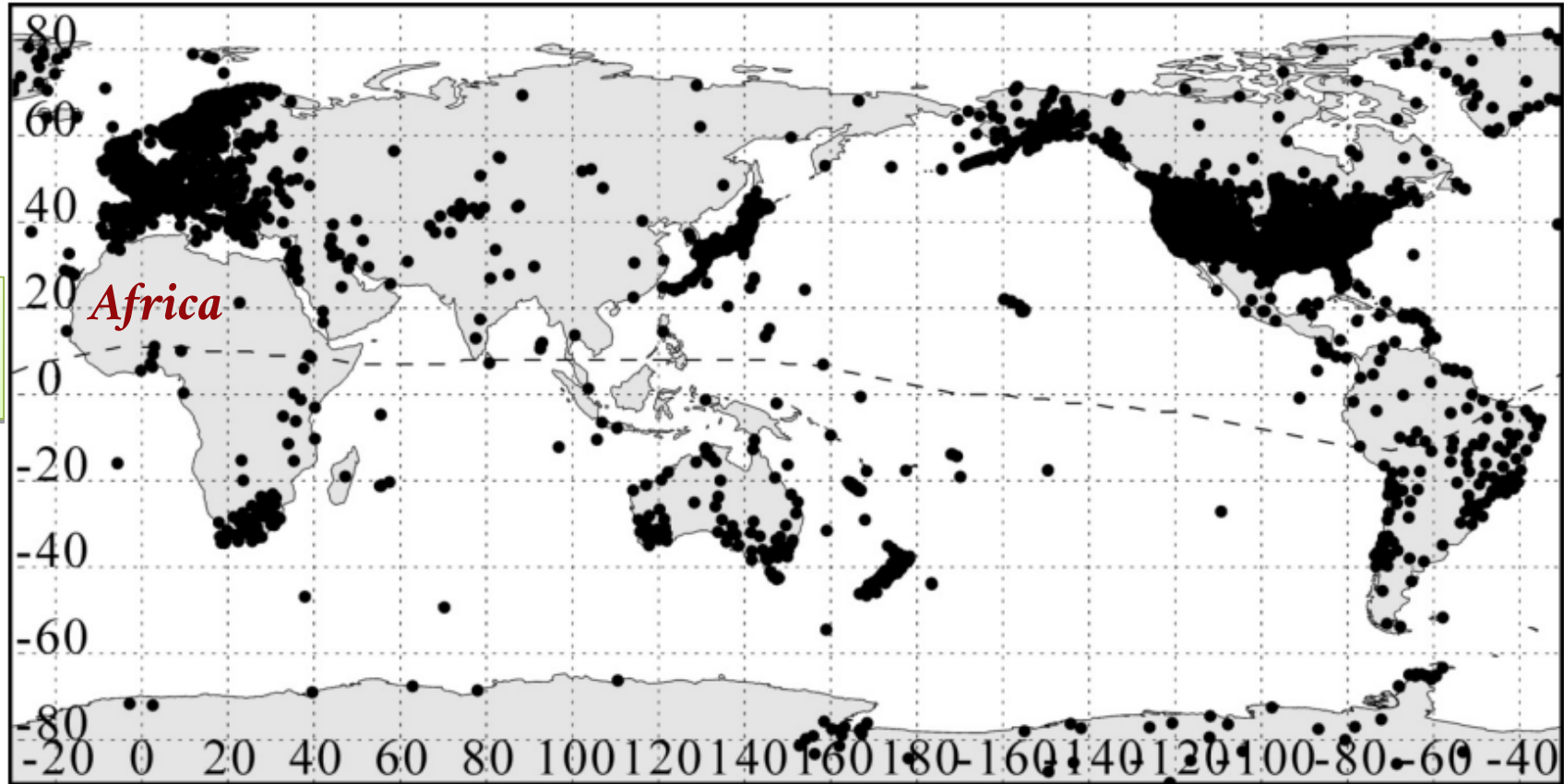
(**Source:** *Abba et al., 2015*)

What is the Total Electron Content?

- Total number of electrons in a pathline

- (1 TECU = 1 x 10^16 electrons/m2)

Deliver corrections of ionospheric interference

Distribution of GNSS receivers

Data paucity!

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

Scientific Questions

Low-cost u-blox receiver
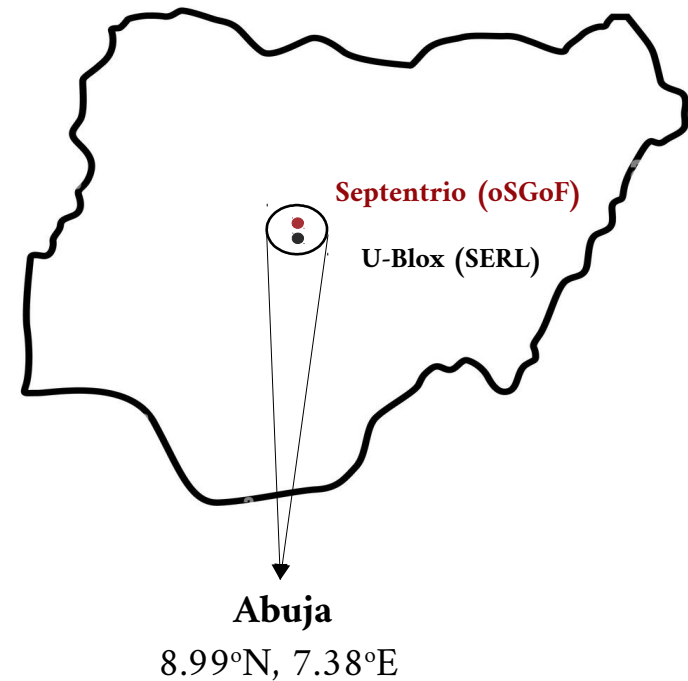

High-cost Septentrio

$400

€9,000

- Can a low-cost receiver compare well with a high-cost receiver ?

- How well does u-blox TEC agree with estimates from AfriTEC and NeQuick ?

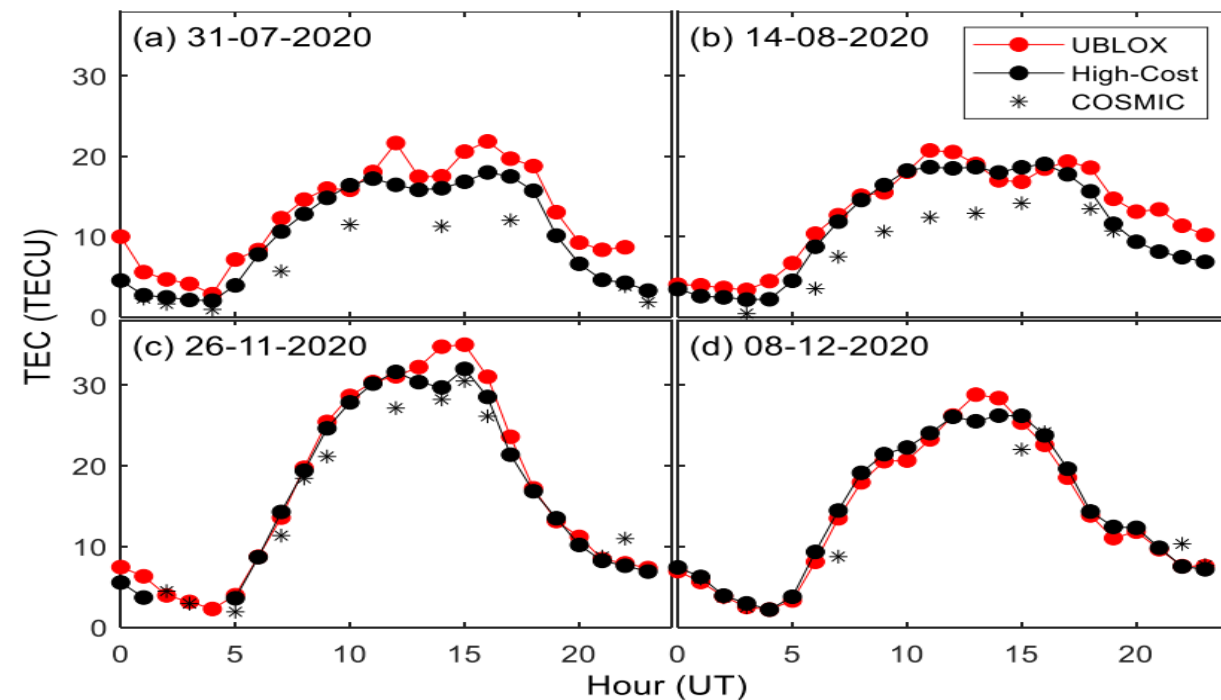- Which low-cost antenna is most suitable for the u-blox receiver ?

Station and Data

July - August and November – December, 2020

Abuja
8.99°N, 7.38°E

Data Sources	References
Low-cost: u-blox ZED-F9P	u-blox.com/en/product/zed-f9p-module
High-cost: Septentrio	https://teronet.nignet.net/
COSMIC-2 mission	https://data.cosmic.ucar.edu/
AfriTEC	https://carnasrda.com/tec-models/
NeQuick	T/ICT4D ICTP, Trieste, Italy

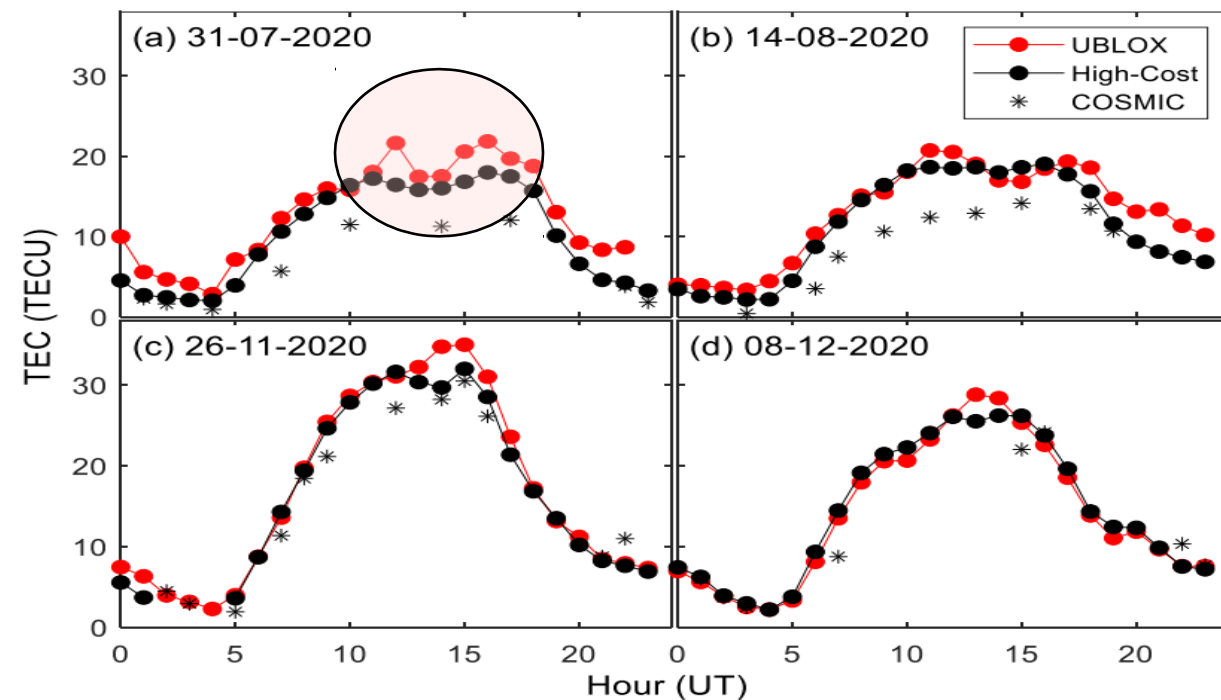# Comparison of TEC from U-Blox, high-cost receiver and COSMIC RO

'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

- Good agreement between the measurements ($R^2 >> 0.8$).

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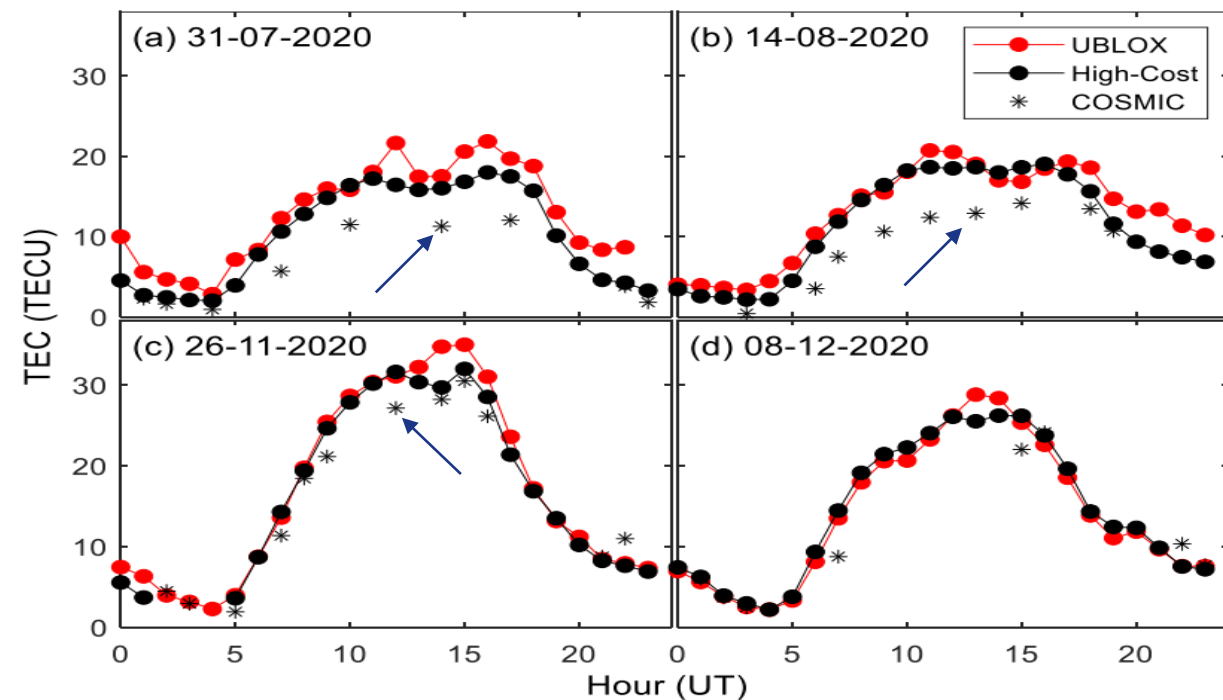
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- Low COSMIC TEC because of integration height.

Stats between U-Blox TEC and TEC values from other 4 sources

	Correlation coefficient				Root Mean Square Deviation (TECU)			
	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

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

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

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

Comparative Check

ANN-MB Antenna

ANN-MB Antenna

TOPGNSS 3-12V RTK

NB: The Same Receiver !

ANN-MB Antenna

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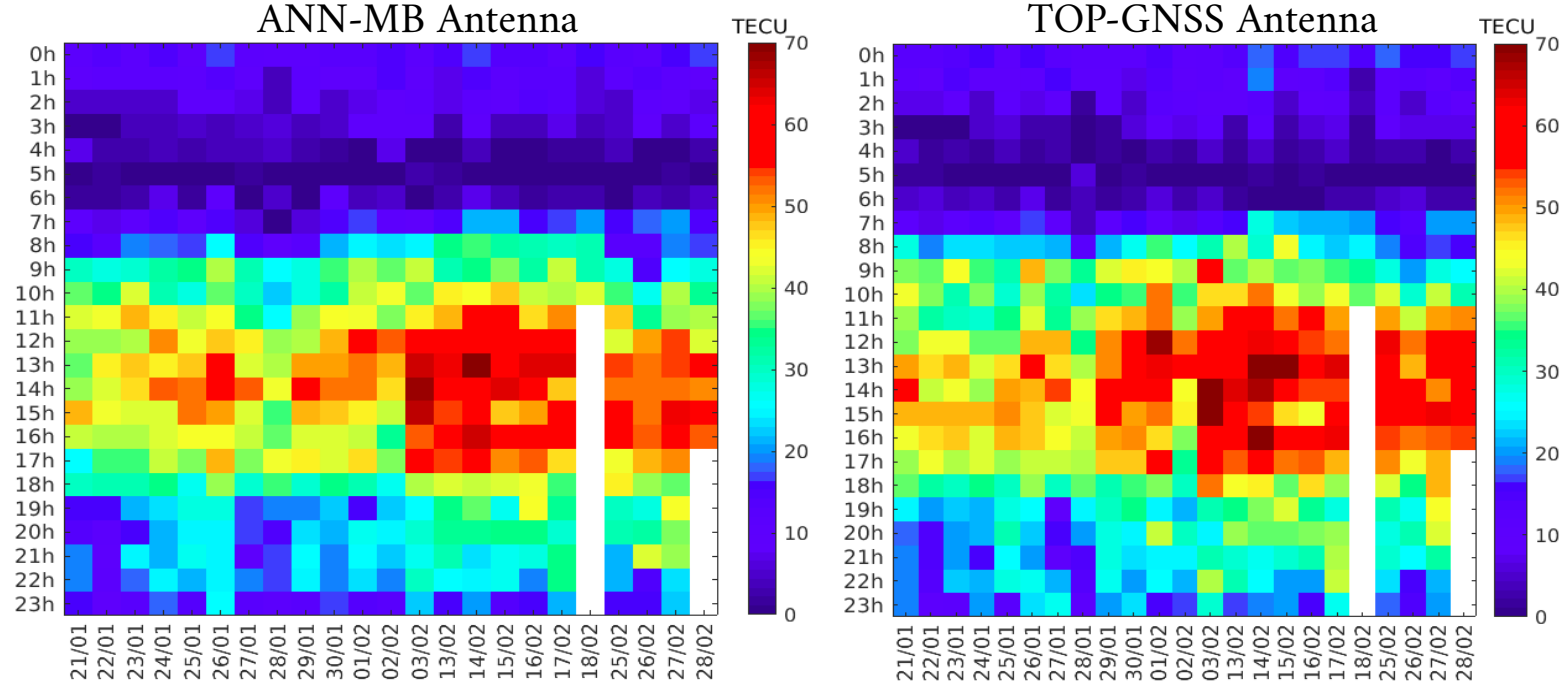
(1) Data from both systems are comparable: $0 \geq TEC \leq 70$.

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

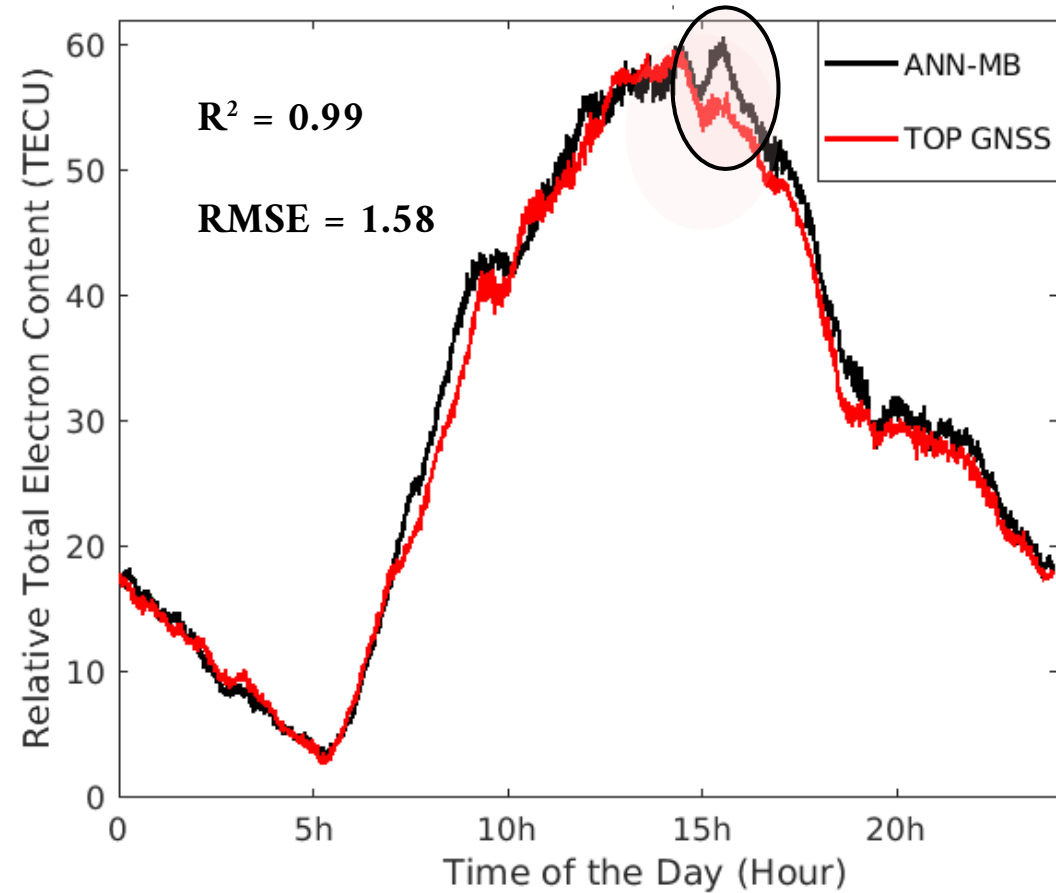1) Comparable measurements- $R^2 > 0.9$.

R^2 = 0.99

RMSE = 1.58
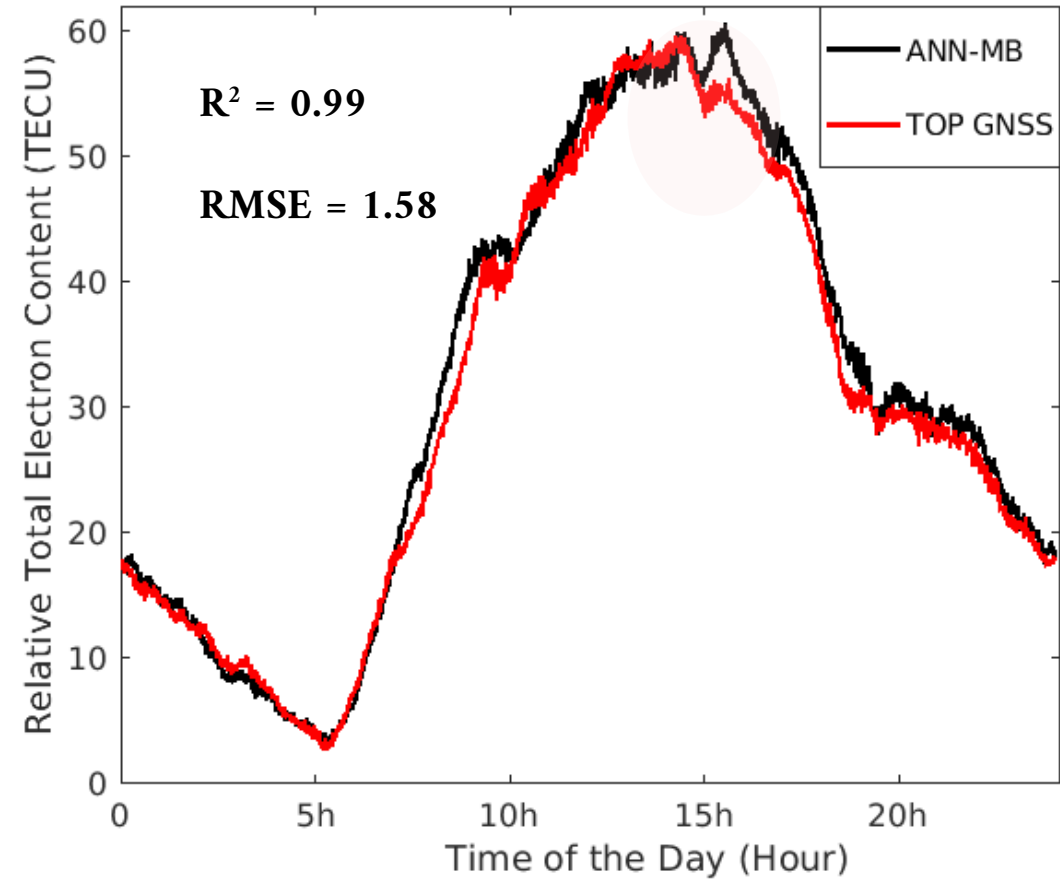
1) Comparable measurements- R^2 > 0.9.

2) Slight discrepancies during the post-noon period.

TEC data of low-cost u-blox receivers compare well with

TEC of high-cost receivers and models.

Perspectives

1) Strategic deployment of U-Blox in Nigeria (ARCSTEE-GNSS initiative).

2) ARCSTEE-NASRDA is ready to collaborate on – Data acquisition; Modeling; Research.

Factors that influence TEC variability

1) Local time

2) Latitude

3) Longitude

4) Season

5) Geomagnetic conditions

6) Solar cycle

7) Solar activity

8) Tropospheric conditions