Responses to interactive comments on**, "Modeling Total Electron Content derived from radio occultation measurements by COSMIC satellites over the African Region"**

By Mungufeni et al.

January 24, 2020

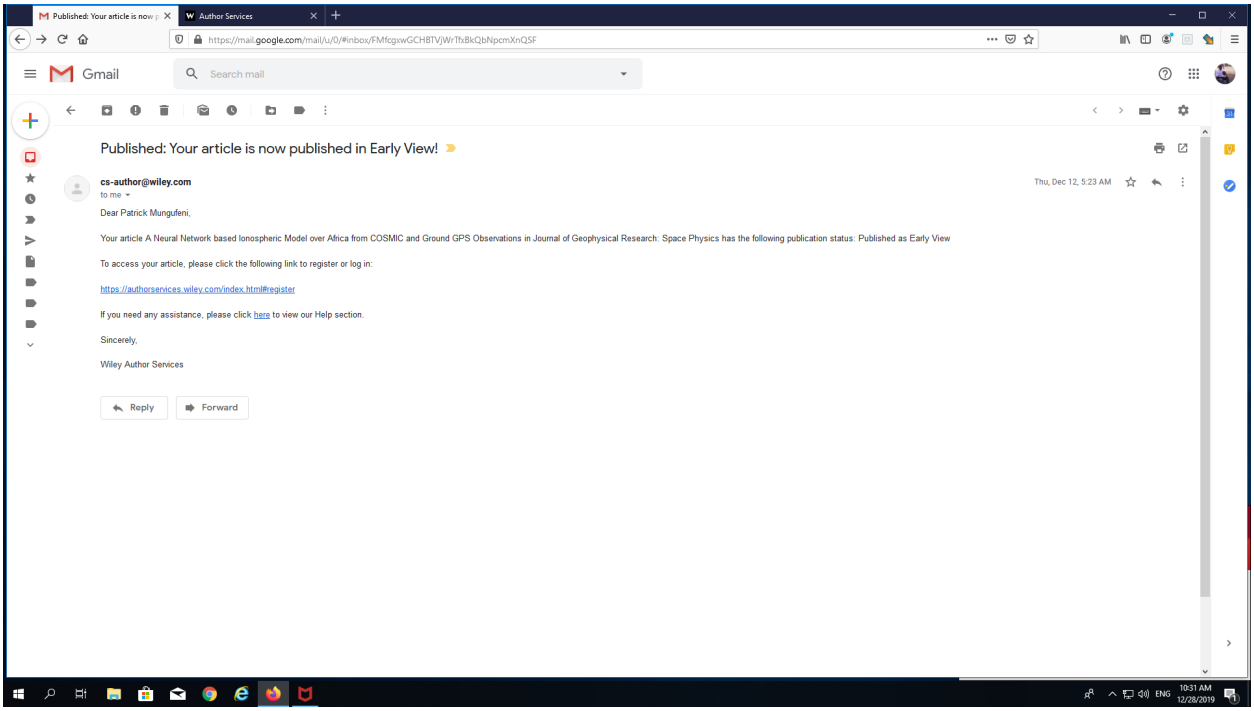
We thank the anonymous referee for the comments.

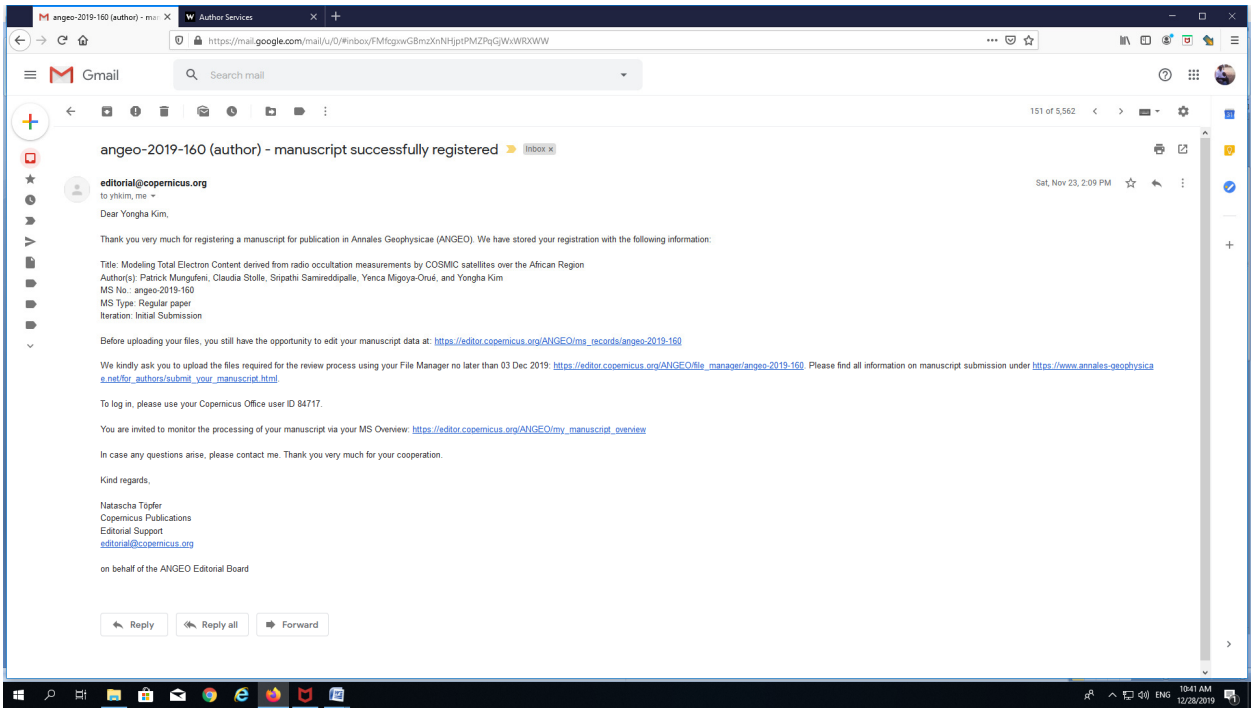
Comment:

An author of this paper (Patrick Mungufeni) along with a long list of other authors have recently published the following paper: Okoh, et al. (2019). A neural network based ionospheric model over Africa from COSMIC and Ground GPS observations. Journal of Geophysical Research: Space Physics, 124. https://doi.org/10.1029/2019JA027065. In that particular paper the authors perform an adjustment using Neural Networks according to which they correct the reasonable discrepancy between TEC from ground based receivers (up to 22000 Km) and occultation measurements up to 700 Km. They seem to apply no such procedure in this paper. This is a major problem of this paper. They also need to make special reference to that paper.

Response:

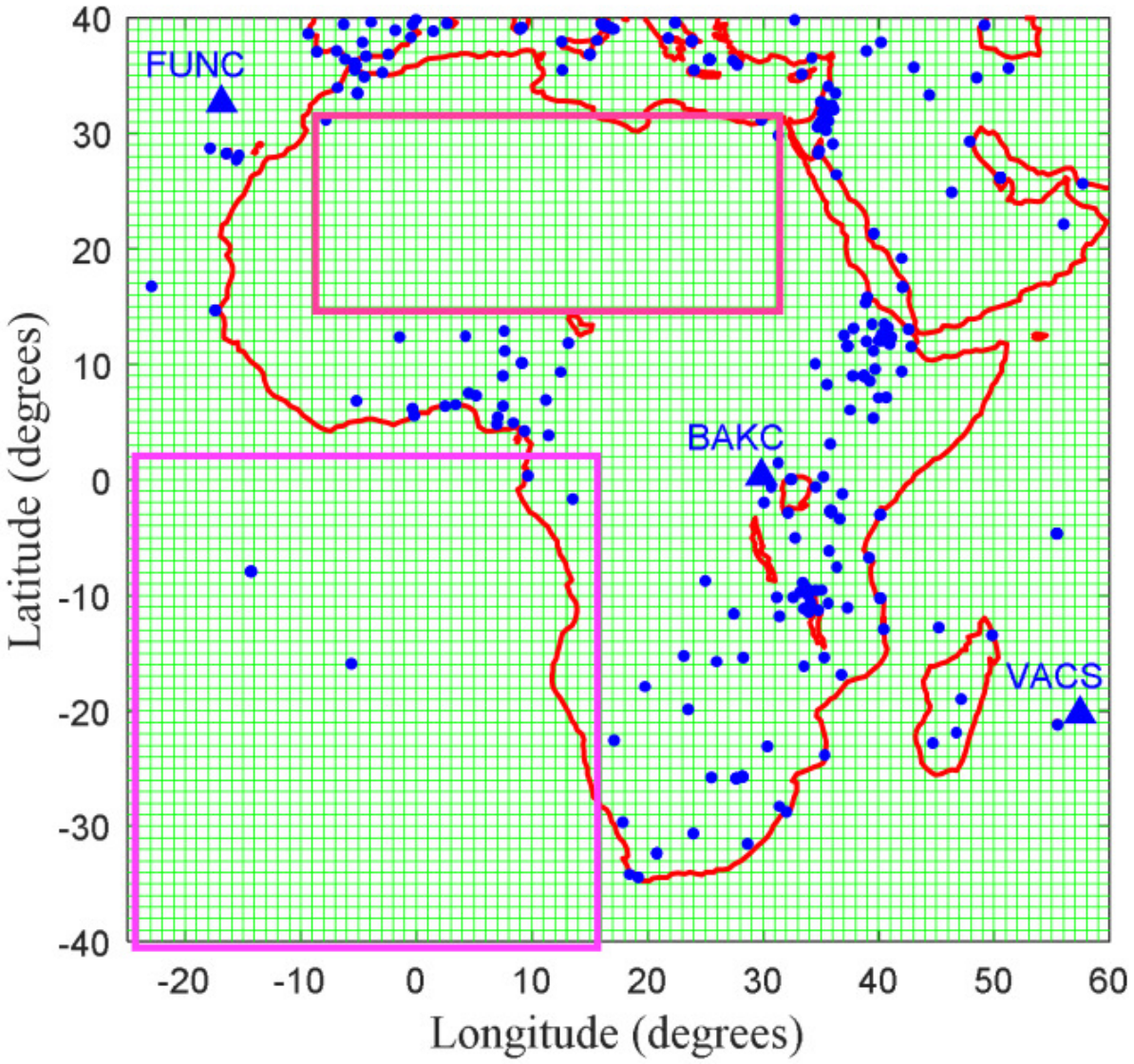
Indeed, Patrick Mungufeni contributed to the paper in the comment which was published on Thur, Dec 12, 5:23 PM. The current manuscript under discussion was submitted on Saturday, Nov 23, 2:09 PM (Korean time). Therefore, we could not reference Okoh et al, (2019) since it was published later after the current submission. Below are the screen shots of emails to prove the dates. Anyway, we shall reference Okoh et al. (2019).





Although the reviewer is recommending creation of data base consisting of both ground and space based TEC measurements, such data base may be subjected to criticism. For example, the observation in Okoh et al. (2019) where the ratio between ground

based and COSMIC TEC varies spatially implies that neural network may not learn the relationship between the two data sets over locations which only have COSMIC TEC data. We have highlighted with pink boxes in Figure below such regions which mostly have COSMIC TEC. The Figure was taken from Okoh et al. (2019). Over pink boxes, the adjustments made to COSMIC TEC may not be trusted because of large distances over which interpolations are done.



When a study opts to have both adjusted COSMIC TEC data and ground based GPS TEC data, some locations will be represented by adjusted COSMIC TEC (remember not trusted) while others will be represented by ground based GPS TEC. Obviously, there is still disparity. For purposes of consistency, It might be fair to use entirely adjusted

COSMIC TEC since it can also be available where there is ground based GPS TEC. Since we do not trust the current known procedures for adjusting space based observations (Okoh et al. (2019) and Mungufeni et al. (2019), *Estimation of equivalent ground-based total electron content using CHAMP-based GPS observations*, Adv in Space Res 64, 199 - 210) the current manuscript used only COSMIC TEC without any adjustment.

Comment:

Maybe they should compare the output of the NN model out of that paper with the output of the spline model for this paper despite that the COSMIC dataset is used as a basis for both models. In this way they will prove their approach for this paper (omitting any correction for the plasmaspheric contribution which is expected to be high at middle African latitudes

Response:

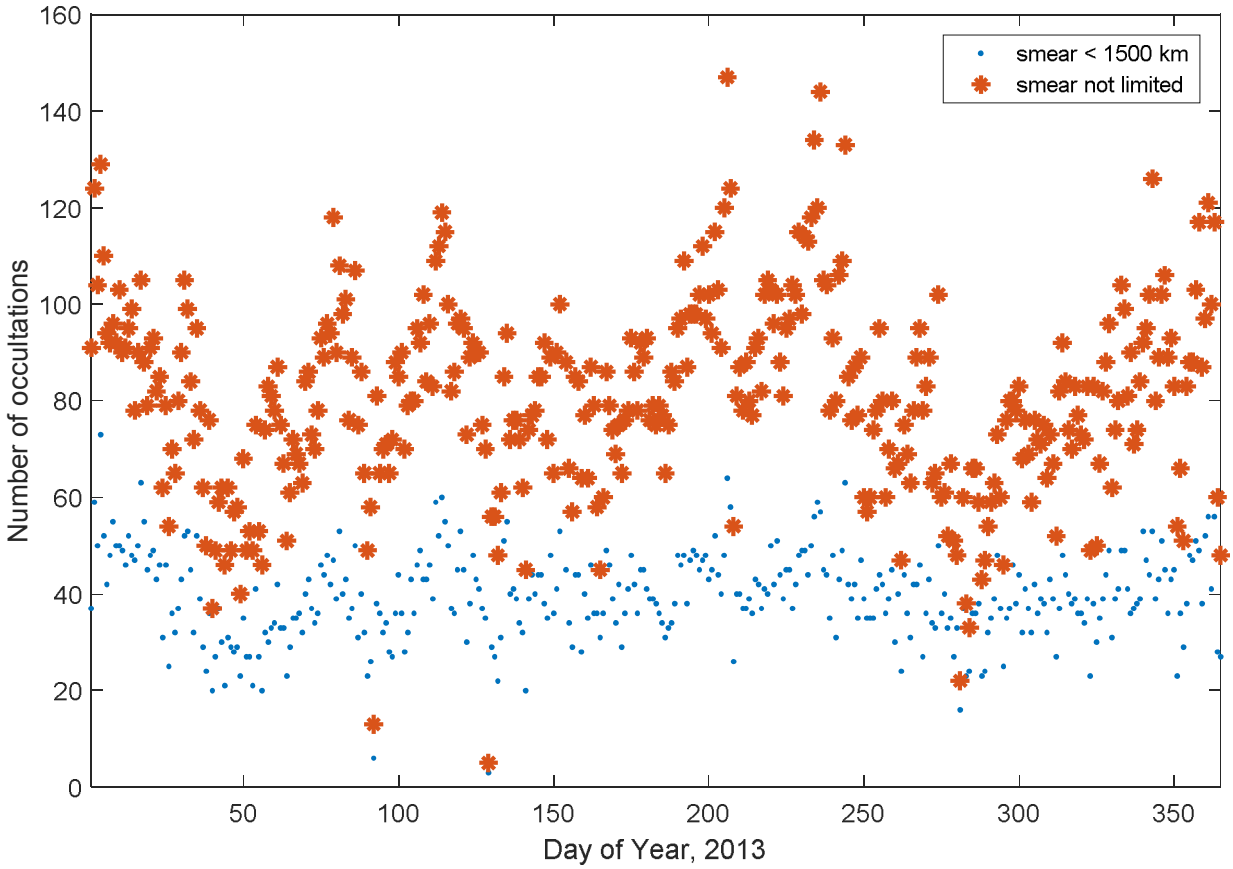
The suggestion in the comment will be implemented.

Comment:

The authors do not provide any scheme by which they would reject any unrealistic COSMIC profiles. There have been numerous validation studies with Digisondes that verify this problem especially in the bottomside.

Response:

Empirical modeling requires adequate data for the mathematical functions to capture the physics inherent in the data. However, to minimize measurement errors, studies that have used COSMIC data commonly reject measurements with horizontal smear > 1500 km. We have presented in Figure below the number of COSMIC TEC measurements per day during the year 2013 over the longitude and latitude ranges of -15 – 60^{o} and -35 – 35^{o}, respectively.



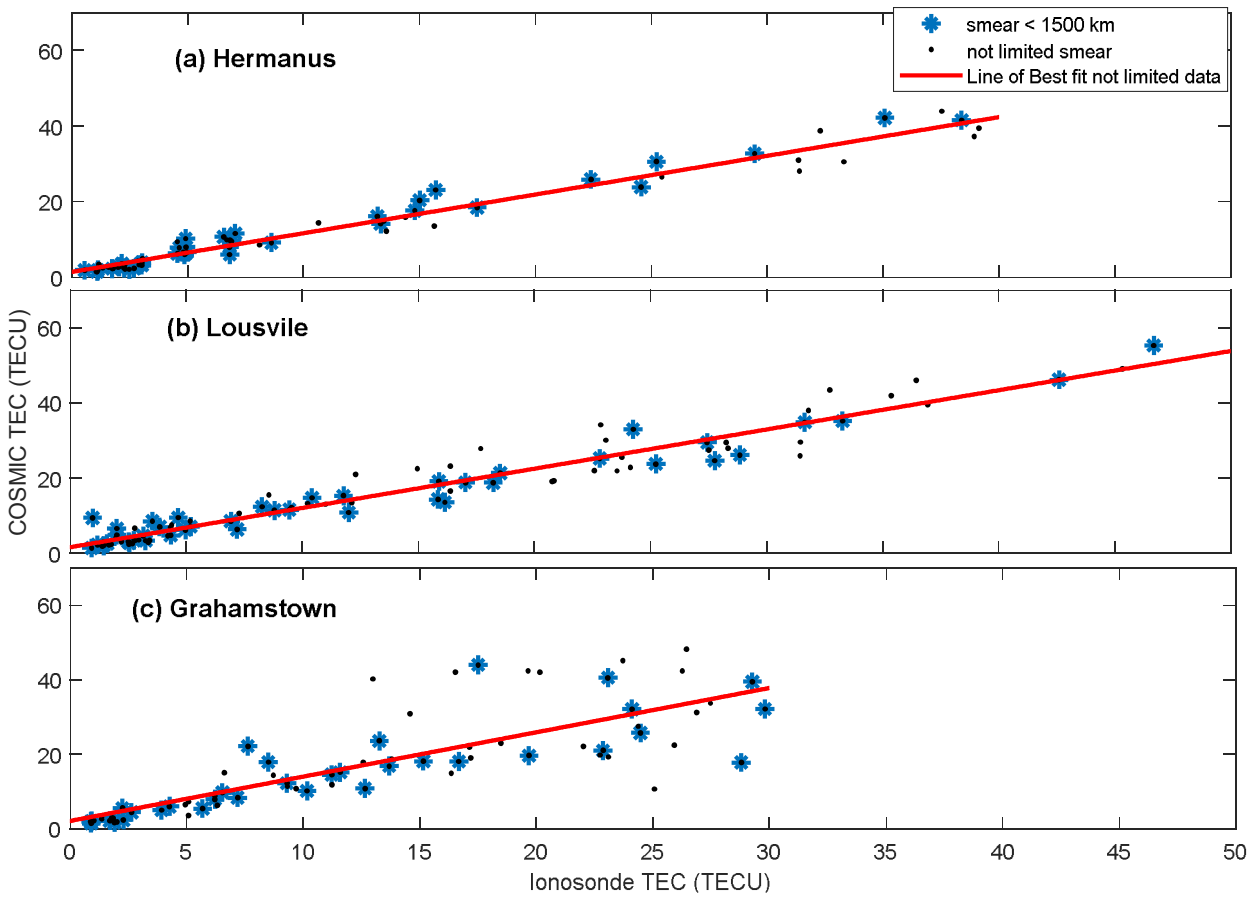
The blue dots indicate COSMIC TEC measurements when the horizontal smear is < 1500 km, while the red stars indicate COSMIC TEC measurements without limitation of horizontal smear. It can be noticed that when the horizontal smear is limited, ~40 observations may be made per day. Obviously, the 40 measurements may not cover very well all the 24 hours in a day and all the grid cells. This shows clearly that the seasonal or day number of year variation does not have good input data for the entire African region. In order to have fairly adequate data, we did not apply restriction to the horizontal smear. Therefore, in a day, there were about 80 observations as shown with red stars in Figure above.

We established that the COSMIC TEC data values with smear > 1500 km do not introduce alarming errors. This was done by analyzing COSMIC TEC data which were coincident with TEC observed by ionosonde stations at Hermanus, Grahamstown, and Louisvale. The observations of the year 2013 were considered. Table below presents the root mean squared error between (i) ionosonde and COSMIC TEC without limiting

the horizontal smear, and (ii) ionosonde and COSMIC TEC with horizontal smear limited to 1500 km.

Station	Smear < 1500 km		No limitation	
	Number of observations	RMSE (TECU)	Number of observations	RMSE (TECU)
Hermanus	38	1.838	65	2.256
Grahamstown	34	6.479	73	7.923
Louisvale	42	2.765	91	3.252

The table shows that the RMSE for the two cases over a particular ionosonde station are not grossly different. Based on these results, trading off accuracy may not be costly compared to trading off adequate need of data. Therefore, we decided not to impose any restriction on the horizontal smear. Although the RMSE appear to be smaller when the smear < 1500 km, some of the data points that were subjected to this restriction are also far from the linear least squares fitting line. See blue stars in Figure below.



Most likely, the ~80 COSMIC TEC data points in a day may not still cover very well al the 24 hours in a day and all the grid cells. This problem might be solved by adopting appropriate data binning criteria. Therefore, instead of binning data according to year, we binned data according to only three different solar flux levels. This technique proved to be good and it was published in Mungufeni et al, (2019), *Characterization of Total Electron Content over African region using Radio Occultationobservations of COSMIC satellites*, Adv in Space Res 65, 19 – 29.

Comment:

I strongly suggest to compare the output of their model with ionospheric TEC (up to 700 km) from all over four stations Digisonde stations over South Africa https://spaceweather.sansa.org.za/products-andservices/current-conditions/ionograms. This will provide a much more realistic comparison test to their model

Response:

The suggestion in the comment will be implemented.