Response to review comments #RC2

Major comments

Comment 1: EOF analysis has been applied to TEC/foF2 modeling in low and middle latitudes, during geomagnetically quiet and storm conditions, and at regional/global scale (References below). In my point of view, the presented work seems to be a repetition of what has been done previously and its contribution towards research progress referring to existing works is not clear. I am suggesting the authors to revise the introduction and include the references provided above and then highlight briefly and concisely their contribution to research progress.

Response: It is true that similar work especially with the modeling technique has been done for other regions. A number of the references suggested have been included in section 3. The focus of this work is on regional trend estimation, and hence the contribution of this work is in terms of using the EOF model as a background in trend estimation and the nature of the trends over the African region. The need for such a study has been stated in the last paragraph of the introduction.

Comment 2: (Page 2, lines: 18 - 19). The authors mention that 2-hour GIM data was interpolated to 1-hour data and it is evident that during interpolation some errors are introduced. I am suggesting the authors to clarify how the interpolation method used in this study has been validated before being applied, and how errors due to interpolation will affect TEC modeling results.

Response: Given the different times for CODE's GIMs (odd hour before 2002, even hours from 2002-2014 and hourly after 2014) it was necessary to interpolate the data to provide a uniform sampling. Before the interpolation, we first extracted the VTEC for each longitude-latitude pair. The VTEC was then interpolated in time domain using linear interpolation. The choice for the linear function was because;

- Piece-wise linear functions are used for representation in the time domain while generating GIMs.
- Linearly interpolated CODE's GIMs have been compared with TOPEX/Jason TEC data (Jee *et al.*, 2010).

Since the basis vectors give the average daily trend over the entire period (1999-2017), we do not think that the choice of linear interpolation of the VTEC would substantially affect the model. In case of daily random errors due to the interpolation procedure, they will manifest in the higher order EOF modes, and these were discarded when modeling the TEC.

Comment 3: Discussion of the results and conclusions should be revised. The authors should highlight the main findings of the current work referring to previous works.

Response: Some of the major findings of this work include;

- The EOF-based TEC model provides a better background TEC over Malindi than the IRI
- Trend of TEC over MAL2 is positive.

- Confirmation of latitudinal variation in trends of TEC over African low latitudes and of negative trends dominating over the geomagnetic equator.

These have been clearly pointed out in the conclusion during the revision.

Minor comments

Comment 1: (Page 3, line 33) The six EOF modes are not elements of the matrix U as stated by the authors. Please remember that EOF modes ($U_j \times C_j$), EOF basis functions U_j and EOF coefficients C_j are different.

Response: Thank you for the observation. The sentence was rephrased to:
The basis vectors of the first six EOF modes in matrix U and their corresponding coefficients obtained using equation 3 are shown in Figure 1.

Comment 2: (Page 4, lines 4 - 7) "The fluctuations ... dynamics". I disagree with this statement. Please refer to the above suggested works and explain correctly what the basis functions U j , j = 2, ..., 6 are describing.

Response: Since the basis modes represent the contribution of each factor in influencing the variability in the data, their ordering may vary for the different data sources. For example, according to Dabbakuti and Ratnam (2017), the second and third order basis function represent the semidiurnal variation associated with the summer to winter annual variation and ionospheric anomaly feature due to prereversal enhancement respectively. However, Dabbakuti and Ratnam (2016) observed that the second and third order base functions describe the variability due to irregularities and scale disturbances. While for our data, the second basis function appears to be associated with prereversal enhancement. It is important to note that, the physical interpretation of the basis functions are normally difficulty due to their geometric nature (Hannachi *et al.*, 2007). To avoid subjective interpretation of the basis functions, we have deleted the sentence "The fluctuations observed in the higher order basis functions could be signatures of the different processes (such as traveling thermospheric disturbances (TADs)) that influence the low latitude plasma dynamics" since no statistical analysis was done for the higher order basis functions.

Comment 3: (Page 4, Figure 1 (a) and (b)) Please clarify in the text that the top left panels of Figure 1 (a) and Figure 1 (b) compare diurnal mean TEC with U1 and solar flux index with C 1 , respectively.

Response: Thank you for the suggestion. The following sentence was added in the text
The top left panels of Figure 1 (a) and Figure 1 (b) compare diurnal mean TEC with the first basis vector U1 and solar flux index with coefficients C1 of the first EOF mode respectively

Comment 4: (Page 4, line 16) A period of 0 means a harmonic function of infinite angular frequency. The statement is incorrect.

Response: It is true that the statement is incorrect. This was changed to:
The EOF coefficients were expressed as a sum of linear and harmonic functions following the

procedure of Zhang *et al.* (2009) as

Comment 5: (Page 4, Table 1) Please specify that the explained variances and cumulative variances are expressed in percentage.

Response: Percentage sign (%) has been added in Table 1

Comment 6: (Page 5, lines 3 - 5) The sentence is wrong. The least square method is used to estimate EOF coefficients from the exact coefficients C j (and not GPS-derived TEC as mentioned) and model inputs. (Please see Equation 5).

Response: Thank you for the observation. The sentence was corrected to:
The coefficients a_{j1} to f_{j3} in equations 4-7 were determined using a least squares fit to the EOF coefficients C_j in equation 3

Comment 7: Specify the inputs of the models in section 2.

Response: We added the sentence below to specify the inputs to the model:
"Based on the observations in Table 2, it was reasonable to use F10.7av and Dst as inputs to model the solar and magnetic dependences respectively of TEC over Malindi. Since these parameters vary with the day of the year (DOY), our third input parameter was the DOY number".

Comment 8: (Page 7) Comment about the failure/inaccuracy of IRI in predicting TEC during storms. IRI and GPS satellites provide TEC up to 2000 km and 20,200 km altitude, respectively. Comment discuss about this and the plasmaspheric contributions.

Response: Thank you for the suggestions. It is expected that the altitude difference would result in lower IRI TEC than GPS TEC due to the plasmaspheric contribution to the TEC. However some observations (eg. Olwendo *et al.* 2012 show that IRI overestimates the GPS TEC during low solar activity years and during June solstice. Such a difference may not be accounted for in terms of the altitude

Like any other empirical model, the IRI is limited. The inaccuracy of IRI in predicting TEC during storms over Malindi probably leaves an open research question. There may be need to improve on the storm model used in IRI in order to capture the different storm time TEC responses.

Comment 10: (Page 6, Figure 3): Add Kp index as the authors have used it to select quiet days.

Response: The maximum Kp and the minimum Dst for each of the days has been included in the plots

Comment 11: (Page 7, Figure 4): Specify in the text that top panels represents Dst index.

Response: The following sentence was added in the text:
"The bottom and the top panels of Figure 4 show variation of the hourly diurnal TEC and Dst index respectively during selected major geomagnetic storms".

References

Jee G., Lee H. B., Kim Y. H., Chung J. K. and Cho J., 2010. Assessment of GPS global ionosphere maps (GIM) by comparison between CODE GIM and TOPEX/Jason TEC data: Ionospheric perspective. J. Geophys. Res.: space physics,115, p A10319

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Hannachi A., Jolliffe I.T. and Stephenson D.B., 2007. Empirical orthogonal functions and related techniques in atmospheric science: A review. Int. J. Climatol., 27, pp. 1119–1152.

Olwendo O., Baki P., Cilliers P., Mito C. and Doherty P., 2012. Comparison of GPS TEC measurements with IRI-2007 TEC prediction over the Kenyan region during the descending phase of solar cycle 23. Adv. Space Res., 49, pp. 914–921.

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