EMPIRICAL ORTHOGONAL FUNCTION MODELLING OF TOTAL ELECTRON CONTENT OVER NEPAL AND COMPARISON WITH GLOBAL IONOSPHERIC MODELS

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Abstract:

- This analysis uses 3 years hourly observations of total electron content (TEC) from 5 global positioning system (GPS) station across Nepal to analyze the spatial trend.
- Empirical orthogonal function base functions and associated coefficients of TEC variability over Nepal have been studied to establish the relationship between observed and modeled TEC values.
- The study shows an hourly pattern of TEC variation in which the TEC rises from dawn, reaches the highest TEC values about 40 TEC units during the peak hours of the day, then decreases at evening at the lowest diurnal values about 5 TEC units. Monthly TEC values over all sites are higher during the march and April (about 38 TEC unit), while they are lower values during December and January (about 10 TEC unit).
- The correlation coefficients between the GPS TEC values and the global modeled TEC values are higher, while it becomes highest with empirical orthogonal function modeled TEC values for both cases of hourly and monthly variations

Introduction:

- The IRI model has provided monthly average ionospheric parameters regarding to date, local time, location, geomagnetic activity, and solar activity at heights up to 2000 km, for instance, electron and ion temperature, electron density, peak height, F2-layer critical frequency (foF2), and TEC etc.
- The IRI-predicted TEC values have been investigated and compared with the measured TEC values over different regions in order to enhance the model effectively and to provide the reference values for the real applications . Although the IRI model has been enhanced to predict the diurnal and seasonal variations of TEC values as practically as
- TEC measurements, multi-GNSS networks beneath International GNSS Service (IGS) have been utilized simultaneously to obtain numerous global total electron content maps with high temporal and spatial resolutions. The GNSS-based techniques provide several advantages in identifying the patterns and constructing the global ionosphere maps (GIMs) for spatiotemporal TEC variations.

Empirical Orthogonal Function

- The TEC analysis results indicate that the EOF method is a feasibly useful tool for data compression as well as physical process separation, and contributes to the comprehensive analysis of overall spatiotemporal variations in ionospheric TEC. Hence, in the present study, the ionospheric TEC data over Nepal region during the years 2017–2019
- The comparisons among the observed GPS TECs, the IRI-2016 TECs, and the GIM TECs are conducted and analyzed regarding both spatial patterns and time variation characteristics.

METHODOLOGY OF EMPIRICAL ORTHOGONAL FUNCTION MODELING

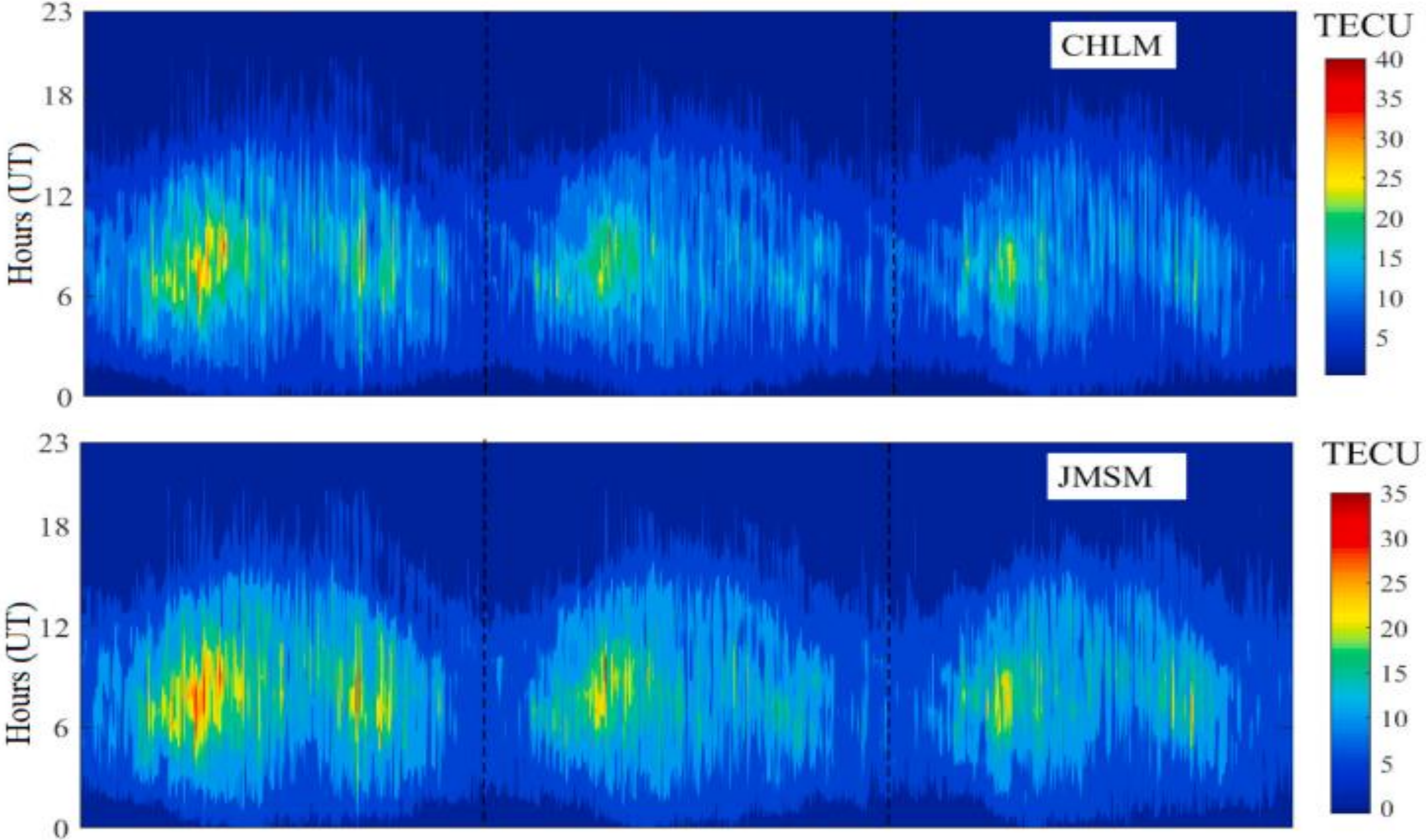
$$A_{k1} = a_1 + a_2F_{10.7} + a_3Ap + a_4Dst,$$

$$A_{k2} = (a_5 + a_6F_{10.7} + a_7Ap + a_8Dst)\cos\frac{2\pi}{365.25}DOY + (a_9 + a_{10}F_{10.7} + a_{11}Ap + a_{12}Dst)\sin\frac{2\pi}{365.25}DOY,$$

$$A_{k3} = (a_{13} + a_{14}F_{10.7} + a_{15}Ap + a_{16}Dst)\cos\frac{4\pi}{365.25}DOY + (a_{17} + a_{18}F_{10.7} + a_{19}Ap + a_{20}Dst)\sin\frac{4\pi}{365.25}DOY,$$

$$CC = \frac{n(\sum Model_{TEC} \times GPS_{TEC}) - (\sum Model_{TEC})(\sum GPS_{TEC})}{\sqrt{n(\sum Model_{TEC}^2) - (\sum Model_{TEC})^2}\sqrt{n(\sum GPS_{TEC}^2) - (\sum GPS_{TEC})^2}}$$

RESULTS



23
18
12
6
0
Hours (UT)
CHLM
TECU
40
35
30
25
20
15
10
5
23
18
12
6
0
Hours (UT)
JMSM
TECU
35
30
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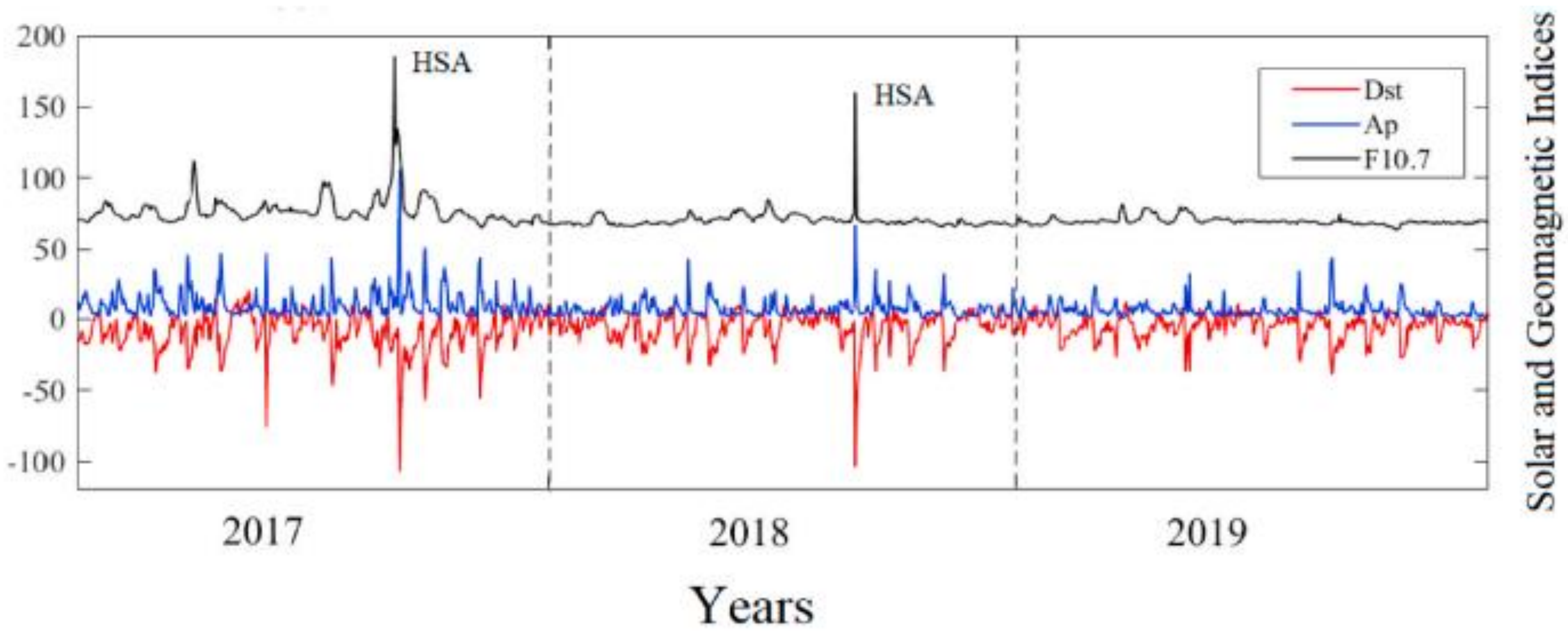
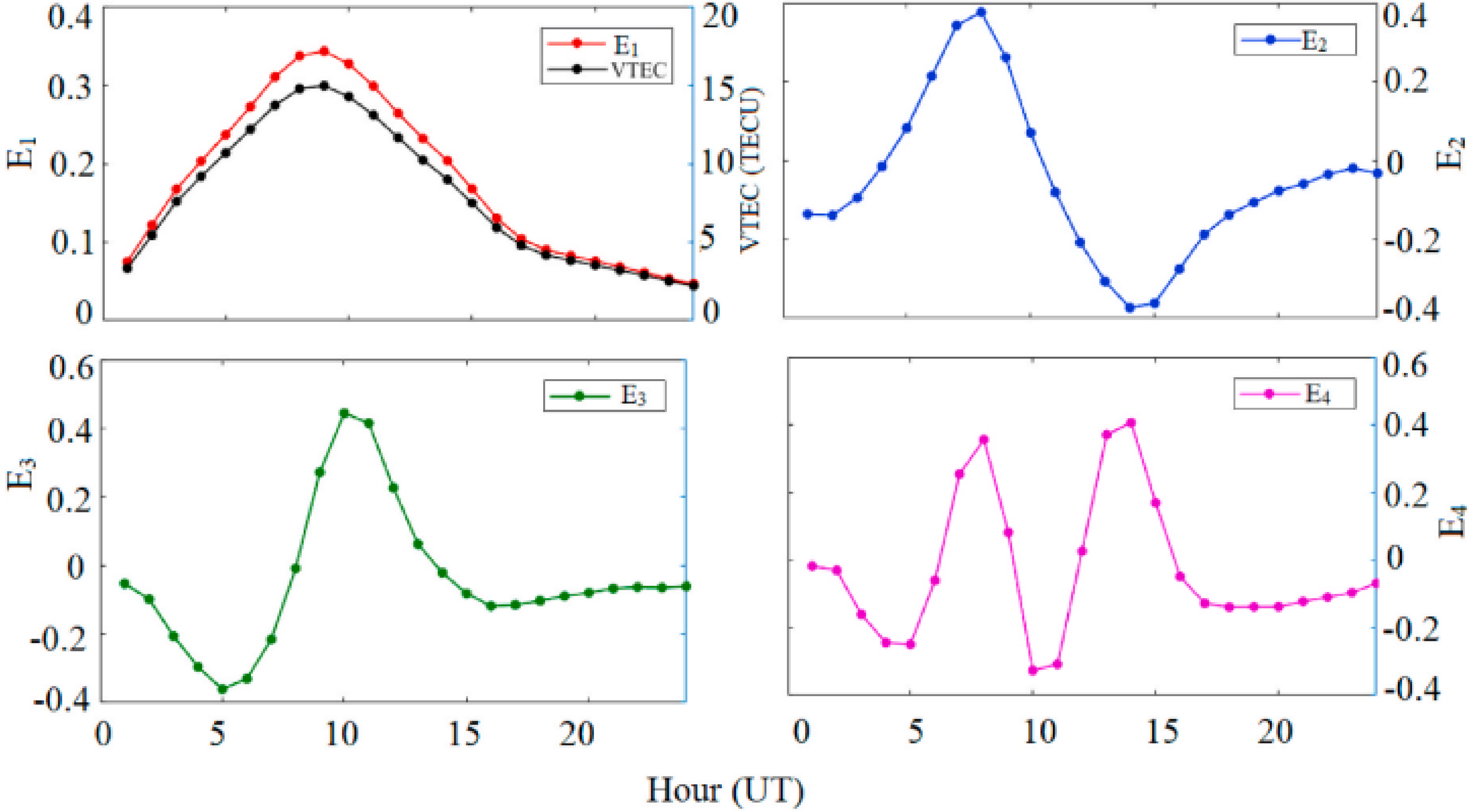
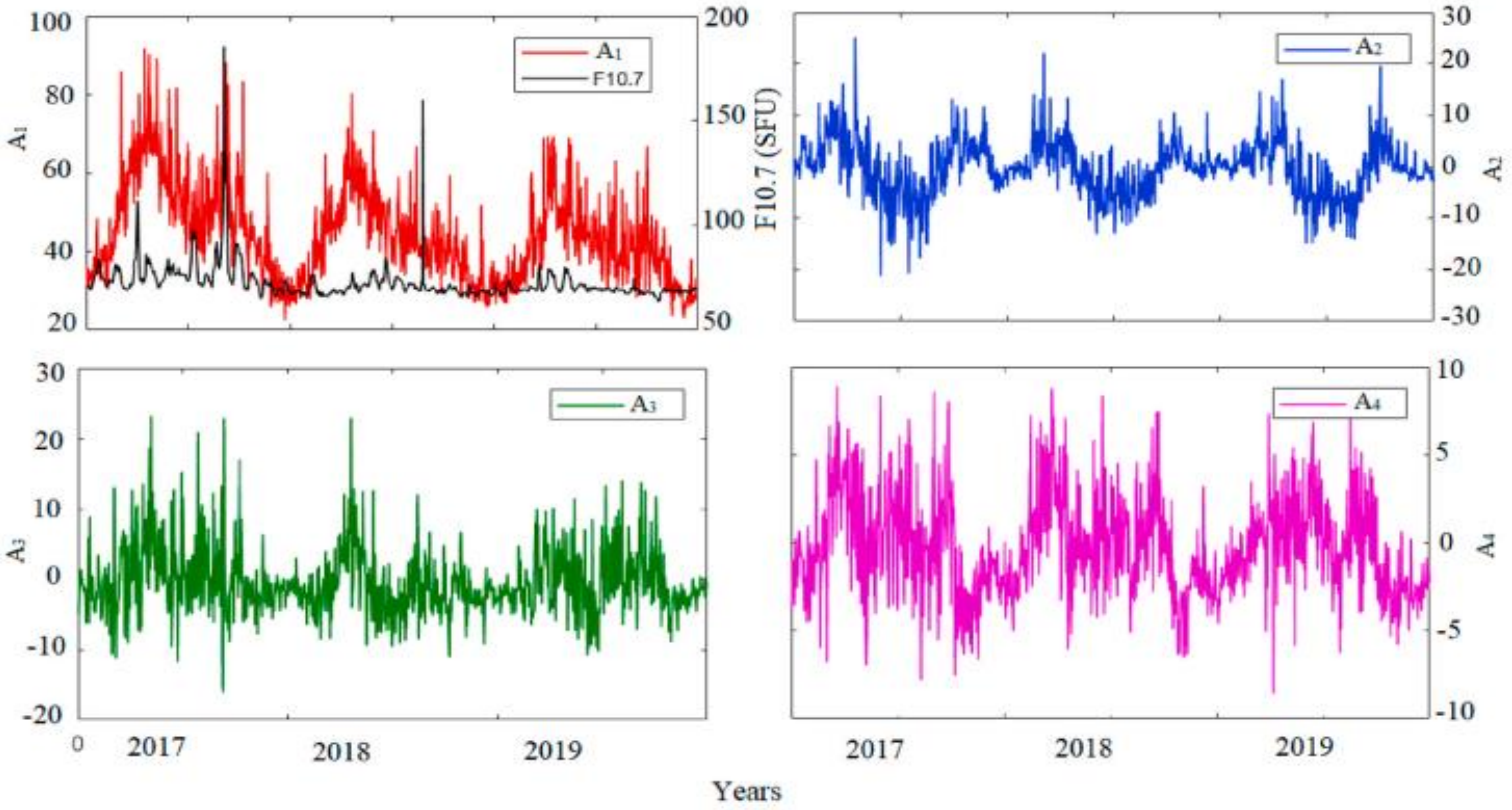


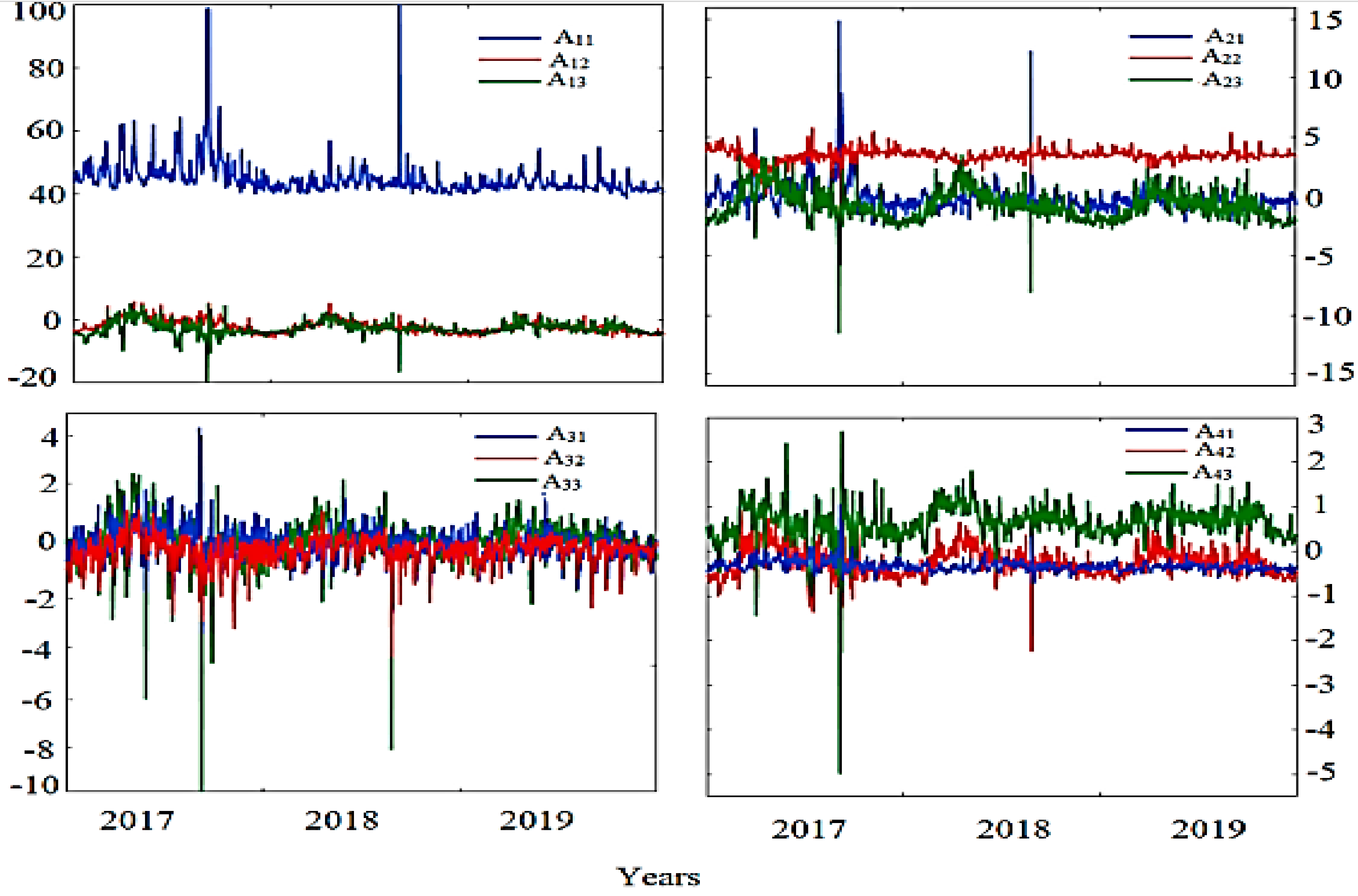
Annual total electron content (TEC) variation during 2017-2019 over CHLM (upper panel) and JMSM (middle panel) sites of Nepal. The lowest panel shows corresponding solar and geomagnetic activity variations during 2017-2019.



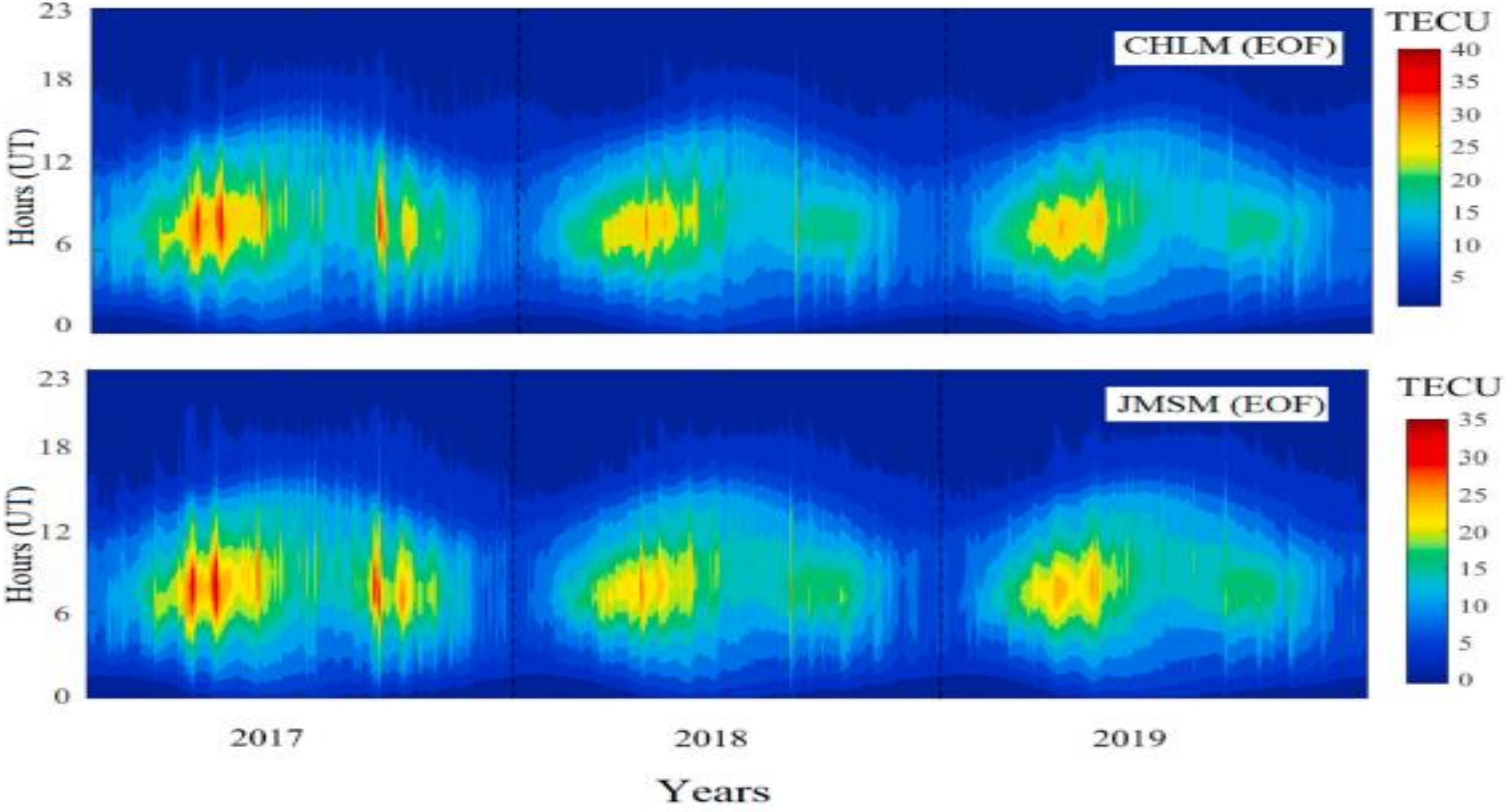
E1
VTEC
VTEC (TECU)
E2
E3
E4
Hour (UT)



A1
F10.7
A1
F10.7 (SFU)
A2
A2
A3
A3
A4
A4
2017
2018
2019
Years

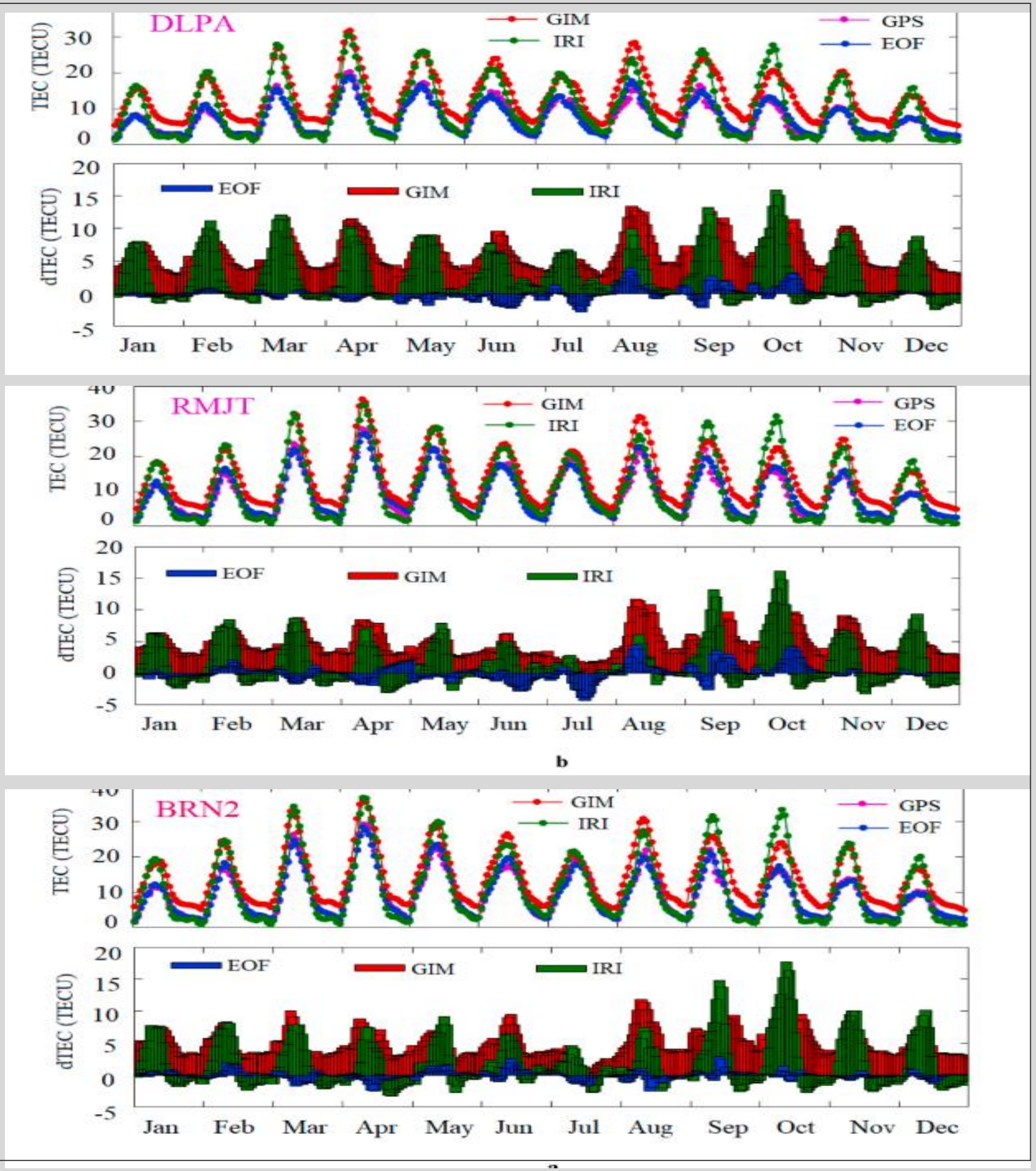


100
80
60
40
20
0
-20
A11
A12
A13
15
10
5
0
-5
-10
-15
A21
A22
A23
4
2
0
-2
-4
-6
-8
-10
A31
A32
A33
3
2
1
0
-1
-2
-3
-4
-5
A41
A42
A43
2017
2018
2019
2017
2018
2019
Years



CHLM (EOF)
JMSM (EOF)
TECU
40
35
30
25
20
15
10
5
TECU
35
30
25
20
15
10
5
0
Hours (UT)
23
18
12
6
0
2017
2018
2019
Years

◦ (a): Monthly global positioning system total electron content (TEC) versus and modeled TEC (empirical orthogonal function, global ionospheric map, and international reference ionosphere) variations over BRN2 site of Nepal. The lower panel shows corresponding dTEC values (model-observed) at BRN2 site. (b): Monthly global positioning system total electron content (TEC) versus and modeled TEC (empirical orthogonal function, global ionospheric map, and international reference ionosphere) variations over RMJT site of Nepal. The lower panel shows corresponding dTEC values (model-observed) at RMJT site. (c): Monthly global positioning system total electron content (TEC) versus and modeled TEC (empirical orthogonal function, global ionospheric map, and international reference ionosphere) variations over DLPA site of Nepal. The lower panel shows corresponding dTEC values (model-observed) at DLPA site.



Conclusion

- . Analysis of TEC variability in the present study shows that the empirical orthogonal function modeled TEC values by using geomagnetic activity are better estimated than the studied global model
- TEC values are poorly represented by global models and need to be improved
- We believe that this study might be beneficial for further consideration of TEC variations and properties over other regions and to improve other existing global models for better prediction