Nonlin. Processes Geophys. Discuss., 1, C911–C917, 2015
www.nonlin-processes-geophys-discuss.net/1/C911/2015/

Nonlinear Processes in Geophysics
Discussions
Open Access

Interactive comment on "The transient variation of the complexes of the low latitude ionosphere within the equatorial ionization anomaly region of Nigeria" *by* A. B. Rabiu et al.

A. B. Rabiu et al.

iobogunsua@futa.edu.ng

Received and published: 12 February 2015

1. REVIEW COMMENTS BY K. UNNIKRISHNAN

This study was conducted using Total Electron Content (TEC) time series for 2011, measured from 5 GPS receiver stations in Nigeria by employing chaotic\non linear analysis. The detrended TEC time series were reconstructed and the values of chaotic quantifiers namely, Lyapunov exponents LE, correlation dimension, and Tsallis entropy were estimated to reveal dynamical complexity of the system. Authors aim to link the chaotic quantifiers and ionospheric behaviour over Nigeria using nonlinear techniques, which is further verified by surrogate data test, and they produced some interesting

results. The paper is well written and worth publishing. I strongly recommend for the publication of this article after minor revision based on the points listed below: 1) The convergence of the computed Lyapunov exponents should be discussed by showing whether they are stable with the change of the embedding dimension, and the time delay. This aspect is very important since the computations of LE depend strongly on the ability to track the dynamical trajectories in the embedded space. For this, in the revised version, authors may present plots for LE versus time delay, by keeping embedding dimension a constant, and also between LE and embedding dimensions, at constant time delay. 2) The wavelike pattern exhibited by LE and Tsallis entropy with the drop in values at equinoxes (Figures 7, 9, 12 and 13) possibly due to self-organized critical phenomenon of the system, is an interesting observation. It would be better if authors could present some more clarifications to link the self-organized critical phenomenon of equatorial ionosphere and the observed wavelike pattern of LE and Tsallis entropy. 3) Axis title and labels for Figures 1,2,7,9,10,11, and 13 are very small in size. Please redraw them with more clarity.

2. AUTHORS COMMENTS

The authors will hereby appreciate the honest observations on our paper and attempts have been made to include the revision points in the main published paper.

3. AUTHORS CHANGES TO THE MANUSCRIPT

I. The first point based on the Stability of Lyapunov exponent at different time delay and at different embedding dimension has been included. Please see Fig 1-2.

II. The second point based on clarification to be made on the Reflection of Self Organized Criticality (SOC) in the ionospheric dynamics will be considered with the inclusion of a new subtopic on SOC in the discussions of the published paper which is explained in the write up below with references.

Reflection of Self Organized Criticality (SOC) in the ionospheric dynamics

The wavelike pattern observed has been described to be as a result of self organized critical (SOC) phenomenon, a phenomenon which has been found to exist in the magnetosphere and the same could exist in the ionosphere, since the magnetosphere couples the ionosphere tightly to the solar wind (Lui, 2002). This was first suggested by (chang et al.,1992,1998,1999; Consolini et al., 1996 Chapman et al., 1998; Freeman and Watkins 2002 and; Koselov and Koselova, 2001. Uritsky et al., (2003) and Chang et al., (1992) pointed out that the existence of SOC in plasma sheet in the tail of the magnetosphere and the entire magnetospheric system is described by the manner in which the magnetospheric dynamics exhibits a number of scale free-statistical relation. This has been verified in many ways from the observations made on local and global characteristics of geomagnetic perturbations as seen in Freeman and Watkins 2002. Perrault and Akasofu (1978) argued that the scale free component of the magnetosphere can be possibly as a result of external perturbations like solar wind. Therefore we can describe the SOC as a specific slowly driven many-body system characterized by an intermittent scale-free response to the external perturbations and global instability, which implies that the system can adjust to rate of changes, as in the case of magnetospheric system without losing its signatures of critical dynamics (Bak et al., 1987; Chang et al., 1992, Uritsky et al., 2003). Similar effects can occur in the ionosphere since the ionosphere is coupled to the ionosphere as mentioned earlier. Therefore ionosphere experiences the effects of solar wind as it impacts the magnetosphere. The lower values of chaoticity at the equinoxes have been suggested to be as a result of the fact that the internal dynamics of the system adjusts itself to the perturbation from the influx of the solar wind which maximizes at the equinoxes. The suppression of the internal dynamics of the ionosphere as a result of its modification by external stochastic drivers like the solar wind has been described by (Unnikrishnan et al., 2006; 2010; Ogunsua et al., 2014). The resulting wavelike pattern might be more obvious at the equatorial region due to the proximity of the region to the sun which lies directly above the equator during the equinoxes. Although there is a scale-free response as mentioned before, the suppressed internal dynamics does not change its signatures

as the ionospheric system retains it chaotic dynamics but only at a lower level. This is described by the drop in the values of the two parameters describing the chaoticity and dynamical complexity of the ionosphere, that is, the Lyapunov exponent and Tsallis entropy.

References Uritsky, V. M., Klimas A. J., and Vassiliadis D.,: Evaluation of spreading critical exponents from the spatiotemporal evolution of emission regions in the nighttime aurora, Geophys. Res. Lett., 30(15), 1813, doi:10.1029/2002GL016556, 2003.

Bak, P., C. Tang, and K. Wiesenfeld, Self-Organized Criticality-an Explanation of 1/F Noise, Phys. Rev. Lett., 59(4), 381– 384, 1987.

Chang, T., Low-Dimensional Behavior and Symmetry-Breaking of Stochastic-Systems Near Criticality-Can These Effects Be Observed in Space and in the Laboratory, IEEE Trans. On Plasma Sci., 20(6), 691– 694, 1992.

Chang, T.: Sporadic localized reconnection and multiscale intermittent turbulence in the magnetotail, AGU Monograph No. 104, Geospace Mass and Energy Flow, (Eds) Horwitz, J. L., Gallagher, D. L., and Peterson, W. K., p. 193, (American Geophysical Union, Washington, D. C.), 1998.

Chang, T., Self-organized criticality, multi-fractal spectra, sporadic localized reconnections and intermittent turbulence in the magnetotail, Phys. of Plasmas, 6(11), 4137–4145, 1999.

Chapman, S. C., Watkins, N. W., Dendy, R. O., Helander, P., and Rowlands, G.: A simple avalanche model as an analogue for magnetospheric activity, Geophys. Res. Lett., 25, 2397–2400, 1998.

Consolini, G., Marcucci, M. F., and Candidi, M.: Multifractal structure of auroral electrojet index data, Phys. Rev. Lett., 76 (21), 4082–4085, 1996.

Freeman, M. P., and N. W. Watkins, The heavens in a pile of sand, Science, 298, 979–980, (1 November), 2002.

Kozelov, B. V. and Kozelova, T. V.: Sandpile model analogy of the magnetosphere-ionosphere substorm activity, Proc. Interball Meeting, Warsaw, Poland, 2001.

Lui. A.T.Y.: Evaluation on the analogy between the dynamic magnetosphere and a forced and/or self-organised critical system. Nonlin. Process in Geophys. 9: 399-407, 2002.

Perreault, P. and Akasofu, S.-I.: A study of geomagnetic storms, Geophys. J. R. Astron. Soc., 54, 547–573, 1978.

III. Finally the comment on the small font size of the title and axis labels for Figures 1,2,7,9,10,11, and 13 will be readjusted for the main published paper.

The authors will also like to state here that additions and subtraction to the main published paper will be subject to editor's recommendations

---

Interactive comment on Nonlin. Processes Geophys. Discuss., 1, 1855, 2014.

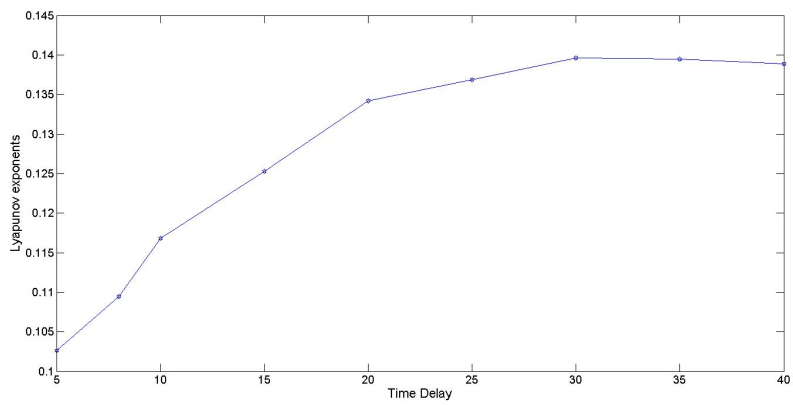
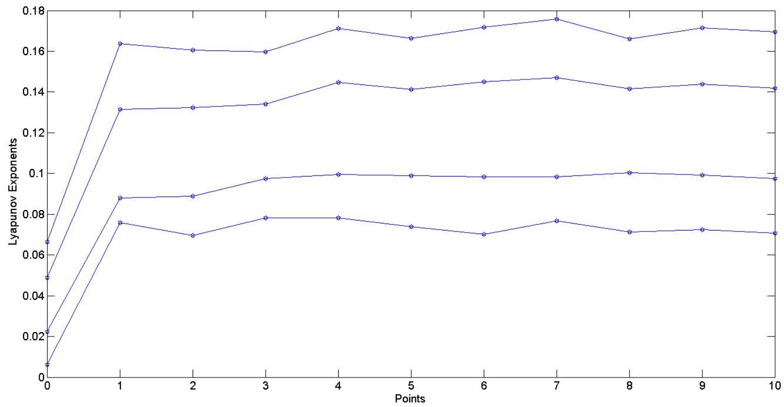


Fig. 1.



0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Lyapunov Exponents
0
1
2
3
4
5
6
7
8
9
10
Points

Fig. 2.