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Interactive comment on "Spread F occurrence features at different longitudinal regions during low and moderate solar activity" *by* Abimbola O. Afolayan et al.

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Referee 3 Major comments: 1. Why the authors consider 2013 as MSA? It is almost the solar maximum of the present solar cycle. It should be HSA, right? For ionospheric studies the solar cycle has to be considered based on sunspot numbers and 2013 may well be considered as maximum period. a) Thanks for your observation. The year 2013 was considered as a MSA year based on the description of the solar flux intervals as specified by past studies including Abdu et al.,2003; Wang et al., 2017. Furthermore, the vertical plasma drift is the major controlling parameter in the study of ESF occurrence and the solar flux dependence of this parameter is well understood

(Abdu et al., 2010; Oyekola et al., 2007). Thus, the focus is mainly the seasonal variation of the ESF pattern across the considered solar flux interval. We will also like to refer to recent studies (Aswathy et al., 2018; Li et al., 2016) where the year 2013 was described as MSA in a similar analysis of ESF occurrence.

2. Equation 1 is confusing and probably wrongly typed. A proper explanation on how Figures 4 and 5 are calculated has to be given. I wonder why the authors cannot simply take '(no. of 15 (or 10) min points with RSF/total no. of 15 (or 10) min points for that local time)x100' to get the occurrence percentage. a) We have deleted the statement which might have caused the confusion about the considered interval. Hence, the highlighted statements have been changed to; "Since the ESF events are very rare during the daytime, our investigation was limited to the time interval between 18:00 – 06:00 LT. The ionograms were examined at an hour interval for the presence of range spread F (RSF) or strong range spread F (SSF). Subsequently, the monthly mean of the RSF occurrence percentage variation over the defined local time interval was then estimated using the relation: hourly occurrence %=(number of ionograms in each hour with RSF)/(total number of ionograms in an hour for that month) $\times$ 100 (1)"

3. For March equinox, why the authors select April instead of March. Isn't it more appropriate if they select March, June, September and December? Anyhow, I believe the results may not vary considerably between March and April. They may cross check and explain. a) Thanks for your observation. We have compared the occurrence rate during the equinoctial months of March and September with the presented results. We found out that the occurrence rate does not vary significantly at these longitudes as you have assumed except during March at the Brazilian station. Where an occurrence percentage of $\sim$70% (88.9%) was observed instead of the $\sim$35% ($\sim$70%) recorded during April of the LSA (MSA). However, a similar equinoctial asymmetry pattern is still highlighted in this region during but the difference observed during the MSA will mean the asymmetry peak will occur at M-equinox. We will make the relevant changes to the FZA station.

4. Line 184 – 186. Ilorin data is unavailable during MSA. So this sentence is not appropriate and there may be variations in local time of occurrences over Ilorin between MSA and LSA. a) Though, the observed large RSF occurrence during LSA means a 50% increase cannot be recorded during MSA as stated but we believe the statement is actually unnecessary and it has been deleted.

5. Line 187 – 188. But from Figure 4, during LSA, September was higher than March over Fortaleza, and also at Kwajalein. a) Thanks for the observation, the statement has been rewritten as; "Unlike the inconsistent longitudinal variation of the equinox asymmetry pattern observed during the LSA period, the M-equinox has a significantly higher RSF occurrence percentage at the CPN, JIC and KWJ stations"

6. Figure 7. Check panels a and b. Are they interchanged? As per statistics Ilorin do not have data during MSA but as per this plot, it does not have during LSA. a) Thanks. We will make the necessary correction to the figure caption (Figure 7b should represent the LSA).

7. Line 291 – 296. Not acceptable based on result. Figure 7 shows that there is no PRE over Kwajalein except for S-equinox of MSA. How it can be an example for control of PRE? a) Thanks for your suggestion. This section has been reviewed and edited to give an improved analysis of our observation.

8. Line 296 – 301. The authors explain based on results of Su et al., (2009). However, with Figure 7 the effect of PRE and associated PSSR can be directly compared and studied. Instead of such an approach why the authors explain the previously reported results herein? May be previous observations can be moved to the introduction. a) This section has been edited based on your suggestion.

9. Figure 8. Is the dip equator for Ilorin correct in this Figure? a) Thanks for your observation, the error was made while converting geographic lat. to geomagnetic lat. using the wdc model (http://wdc.kugi.kyoto-u.ac.jp/cgi-bin/kp-cgi). We have changed it to the quasi-dipole latitude (deg).

10. The text sizes in the Figure labels are small. Enlarge them so that they will be easy to read. a) Thanks for the observation, this will be corrected

Minor comments: 11. Line 18. The authors mention 2009 or 2010 and 2011 or 2013. What do they mean? Is it like '2009 to 2010' or '2009 and 2010'? a) This has been corrected. The data were taken during Oct, 2009 (72.14 sfu) was only used to represent the RSF occurrence at this region during the LSA period due to the low data availability during Oct, 2010 (81 sfu) at the Jicamarca station. We assumed that there will be negligible difference between the background ionospheric condition and subsequently the ionospheric parameters driving the spread F initiation at this region during both years. The highlighted statement will be deleted and the specific season and station where data was taken in the year 2009 will be indicated during the manuscript review.

12. For all the locations, include quasi-dip latitudes also. a) Thanks for your suggestion. This will be added 13. Lines 47 – 50. While PRE is an important parameter for spread F occurrence, recent works indicate that lack of PRE do not preclude formation of spread F. Spread F forms without PRE as well. This need to be discussed and the identification of late night spread F in many of the previous works have to be cited. Some relavent references are Sastri, Ann. Geophys., 1999; Stoneback et al., JGR, 2011; Candido et al., JGR, 2011; Narayanan et al., EPS, 2014. a) Thanks for your suggestion. We have included the following sentences;

"Though, recent studies (Candido et al., 2011; Narayanan et al., 2014; Stoneback et al., 2011) have also analyzed the probable role of several other parameters involved in the plasma irregularity initiation over the period characterized by weak background ionospheric condition. Observation of large ESF occurrence rate during the low solar activity has been attributed to the modulation of the post-sunset electrodynamics by the gravity wave induced perturbation electric field (Abdu et al., 2009; Aveiro et al., 2009). While the neutral wind intensity and direction is a dominant factor in the observed post-midnight ESF occurrence pattern (Dao et al., 2017; Sastri et al., 1994)."

14. Line 53 – 55. Distortion of HF signal quality does not affect GPS frequencies. During spread F times, quite often the L band signals themselves get affected. Rewrite accordingly. a) This has been changed to "...often distort the L-band signal, thereby causing...". 15. Lines 57, 58, 417. Singular to plural: 'ionopsheric conditions', 'deliberate efforts', 'charged particles'. a) The suggested changes have been made accordingly

16. Lines 75 – 77. Initiation depends on seeding also. Though authors are aware of it as discussed in later part of the paper, this statement needs to be rewritten. a) Thanks, this has been corrected. "Hence, the large vertical drift enhances the plasma instability triggered by the seed perturbation and subsequently the R-T instability growth rate."

17. Line 82. The references here are not complete. The first works where STBA hypothesis had originated are not given. Give Maruyama and Matuura, 1984 and Tsunoda, 1985. a) Thanks, we have added the suggested references

18. Line 83. Polarization field or PRE field? a) It has been changed to "PRE"

19. Line 116. Remove initials of Dr. Galkin in the reference. a) This has been edited

20. Figure 1 caption. What is shown is geographic latitude longitude map, while the captions claim 'geomagnetic location'. a) Thanks, this has been corrected.

21. Line 208 – 209. '..both stations..'. Which ones? Give the names. a) The names (JIC and FZA) have been included

22. Line 214 – 215. But Figure 6(b) shows differences between MSA and LSA in S-equinox and D-solstice period. Particularly during S-equinox. Justify or modify the statement. a) This statement has been deleted and the preceding statement edited as; "The observed inverse solar flux dependence pattern at the Brazilian longitude during the S-equinox could be an effect of the solar flux dependence of the density scale length on the RSF occurrence percentage during this season. While the S-equinox and D-solstice seasons are considered to have a very conducive ionospheric condition

for the generation of ESF at this longitude region during LSA."

23. Give expansion of PSSR in first place of occurrence. a) Thanks for the observation

24. Line 229. '..the generation of post-midnight ESF events'. a) Thanks, "generation of" have been added to the sentence.

25. In Figure captions either give full station names or give abbreviations, consistently. a) This has been corrected to full station names

26. Line 252 – 255. How zonal wind affect the vertical plasma drift? Explain briefly. a) Thanks for the correction, the "zonal wind" has been deleted from the sentence.

27. The explanation of terms L and gamma are missing in Equation 2. a) The equation has been deleted based on the suggestion of Referee 1

28. Line 332 – 334. Give references for the sentence 'post-sunset vertical drift was established to have a directly proportional relationship with the neutral density'. a) References have been added.

29. Line 363. I disagree. There are indications that ITCZ may influence ESF activity. It is not established yet. More research is required in this regard. a) We sincerely appreciate your observation with regards to our analysis of the probable influence of ITCZ on the seasonal distribution of ESF activities. We have attempted to demonstrate the complementary role of the gravity wave (GW) in the solstitial asymmetry observed at the low declination angle region using OLR measurement as a proxy for the seasonal distribution of the GW activities at each region. We assume your reservation about this approach might be connected with the results from Su et al., (2014). However, a recent study has attributed the poor correlation at some of the regions with the averaging of OLR value over a wide longitude range (Li et al.,2016). Furthermore, our result showed that the suggested approach does not increase the correlation coefficient at CPN. Hence, we have presented a brief the major factors that could have contributed to the small ESF occurrence percentage at the CPN longitude in spite of the large

OLR frequency. We agree with the opinion that more study is required to fully establish the relationship between the occurrence of OLR measurement and the observed RSF, while we hope the suggested perspective in this paper contributes to the related discussion.

30. Line 368. Briefly explain GWBA hypothesis herein. In the course of discussion, the authors mention it, but some rearrangement is needed to make the flow of paper proper. a) This section has been re-arranged and some part moved to the result section as suggested by referee 1.

31. Figure 8. Explanation of how the plot is made have to be given. How many years of OLR data are used? a) Thanks, and we have added more relevant information to the description of the plotted data.

32. Lines 436 – 443. The description is confusing. May consider rewriting more clearly. a) This section has been rewritten as suggested

“The zonal variation of PRE is relatively small across the longitudinal range 90oE – 120oE and 160oE – 240oE, which encloses the CPN and KWJ stations respectively. The weak PRE at CPN results from the large magnetic field strength and a small field line integrated conductivities at this longitude sector. While the zonal E field was shown to have the minimum value at the KWJ longitude region and consequently the generally weak PSSR observed at these regions during the LSA (Figure 7b.). Under such circumstance, the GW-induced perturbation electric field might have a negligible impact on the instability growth across these longitudes in spite of the large OLR frequency. Hence, the negative correlation observed between the OLR frequency and the RSF occurrence percentage at both sectors is associated with the unfavourable background ionospheric condition for the plasma irregularity growth.”

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