Response to Reviewers' Comments

Revision 1

Reviewer 1

This paper is very interesting, but it is necessary significant improvements before publication. Please, consider the suggestions following:

Authors' Response

Authors would like to thank reviewer for spending his/her precious time to read and comment on the paper. The comments from the reviewer have certainly helped improve the quality of the paper. All changes made with reference to the reviewers' comments are highlighted in red in the revised manuscript.

Reviewer 1

1. The main point is the lack of manuscript organization. The authors need to include more information and the discussion about the anti-correlation.

Authors' Response

Considering reviewer's comment, following sentences have been added at the end of "Introduction" section:

"Correlation coefficient in this paper has been used to study the linear relationship of meteor counts and the intensity of Es layer in their diurnal and seasonal variation. On the contrary, anti-correlation would mean that variations of the two independent observations during the observational period have opposite linear trends."

Reviewer 1

2. Abstract- Lines 13-15: The authors need to include more details about the results.

Authors' Response

Last sentence of the Abstract has been modified as follows to indicate more details about the outcomes of the study:

"The trend of monthly averages of Es layer intensity shows a maximum in late spring and early summer months and a minimum in winter months whereas the meteor counts were highest in winter months and lowest in spring and early summer months. This shows that the presence of Es layer and the meteor counts have no correlation in time, both diurnally and seasonally, which leads us to conclude that the presence of meteors is not the main cause of the presence of Es layer over Arabian Peninsula."

Reviewer 1

3. Introduction: I suggest that authors include 2 or 3 paragraphs about the previous study of the Es layer behavior over the Arabian Peninsula and the wind shear and meter relationship.

Authors' Response

The authors were not able to find any previous studies about the relationship between windshear and meteors over the Arabian Peninsula. The only study reporting the observations of meteors over Arabian Peninsula is by Fernini et al., (2020)." Following para has been added for the previous studies found which studied the behavior of Es Layer:

"The behavior of Es layer over Arabian Peninsula has not been studied by many. Recently, Shaikh et al. (2020a; 2020b) demonstrated the relationship between L-band scintillation and the occurrence of the Es layer over the Arabian Peninsula. The study also revealed a consistent presence of Es layer during the nighttime hours, between sunset and sunrise."

Shaikh, M., Gopakumar, G., Hussein, A., Kashcheyev, A., & Fernini, I. (2020b). Daytime GNSS scintillation due to Es over Arabian Peninsula during low solar activity. Results In Physics, 20, 103761. doi: 10.1016/j.rinp.2020.103761.

Reviewer 1

4. The last paragraph of the Introduction (lines 43-45) needs to be more specific with the authors' results in this work.

Authors' Response

Following line have been added at the end of the 'Introduction' section:

"It has been observed that the presence of meteors is not the main cause of the presence of nighttime Es over Arabian Peninsula since the Es layer intensity (average critical frequencies of the Es layers (foEs)) show no seasonal correlation with the number of meteors observed."

Reviewer 1

5. The authors need to explain Figure 1 and Figure 2 in more detail and maybe include the examples of ionograms since the Es layer are different forms in each region.

Authors' Response

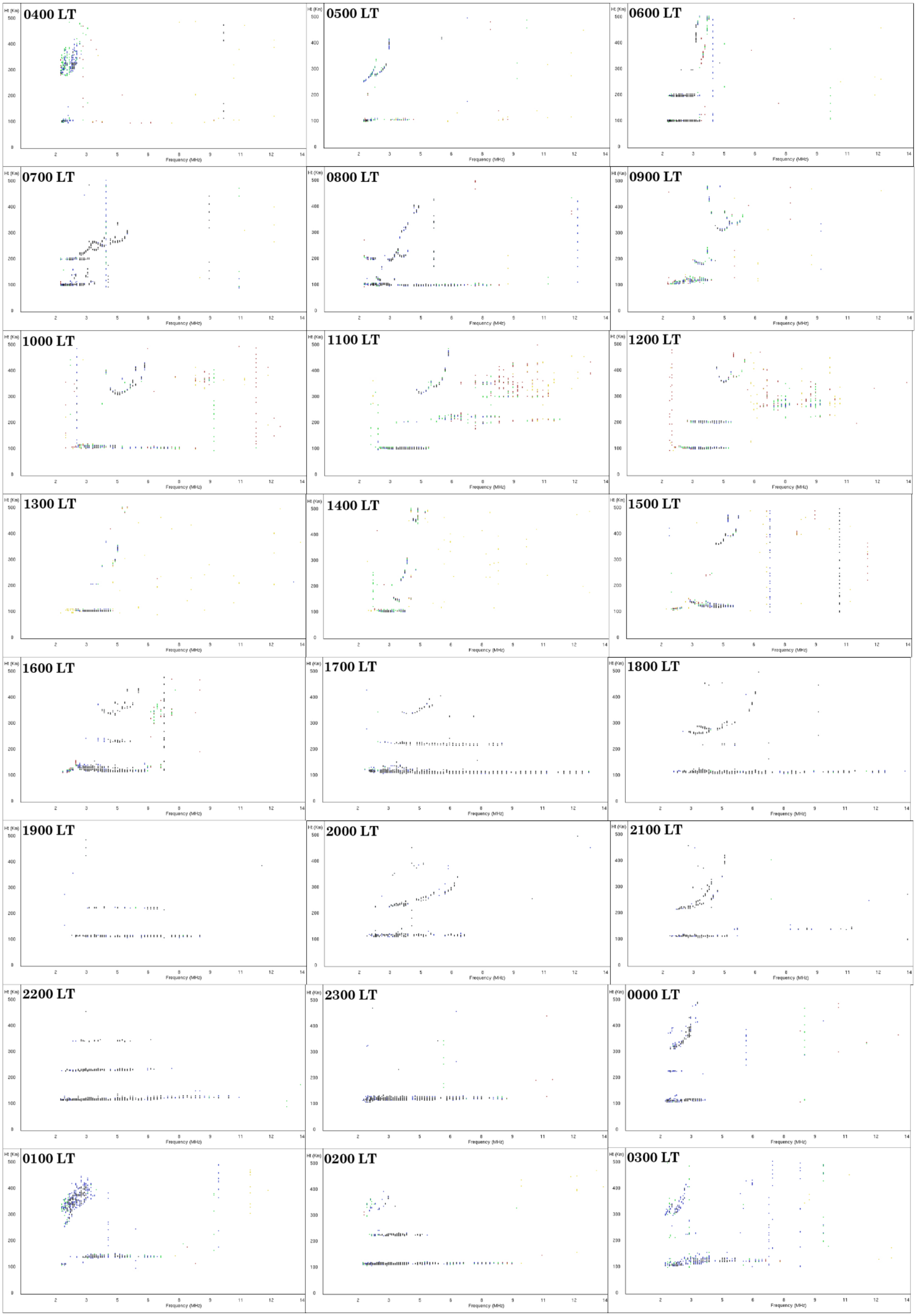
Considering reviewer's comment, the first paragraph of the section 'Data and Methodology' has been modified to include more details about Figure 1, as follows:

"The meteor counts for this study has been obtained in collaboration with the UAE Meteor Monitoring Network (UAEMMN) project (Fernini et al., 2020). The project aims to monitor and detect meteors' occurrences in the region above the United Arab Emirates from sunset to sunrise. To do so, three monitoring towers have been constructed and installed in different parts of the country. For each tower, sixteen cameras are distributed along a ring-like structure with lenses of 6mm and 8mm, while the 17th camera utilizes a wide-angle lens and is located at the center of the structure (Fernini et al., 2020). Following a simulation using Systems Tool Kit software (STK: https://www.agi.com/products/50 stk) as shown in Fig 1a, the towers' locations were selected as illustrated in Fig 1b (made using © Google Maps). In Fig 1, green color represents the area of the sky covered by the 8mm lenses, while the red represents the coverage of the 6mm lenses. The yellow squares show what the wide-angle lens can see and cover. Thus, the STK simulation illustrates how much each tower covers of the UAE sky, and this adds up to 70% coverage of the sky. Each of the three UAEMMN towers employs the use of the UFOCapture Software developed by SonotaCo (SonotaCo, 2005) to detect meteor occurrences. The software can detect movements from the feed of the cameras on the towers. If a movement or action is detected, it writes the video of the action to the hard disk of the computer, from a few seconds before the action is recognized to a few seconds after the action is completed. During the night, the bright streaks produced by a meteor burning up in the atmosphere allows the software to easily detect movements from the sudden changes in pixel values."

The second paragraph of the section 'Data and Methodology' has been modified to include more details about Figure 2, as follows:

"Two other software, UFOAnalyzer and UFOOrbit, also developed by SonotaCo (SonotaCo, 2007a; SonotaCo, 2007b), are used to calculate parameters that define the meteorite. UFOAnalyzer can calculate the direction and elevation of the meteorite occurrence. If the meteorite is detected by two or more sites, UFOOrbit can calculate the orbit and the radiant point of the meteorite. Fig 2 shows a radiant map obtained as the result of analyses by the software. The radiant map shows radiant points on a sinusoidal projection map of the observed meteors, which is defined as the point in the sky from which the path of the observed meteor begins. For a radiant point to be plotted on the map by the software, a double detection of the meteor should occur, meaning that two cameras from at least two different towers need to observe the same meteor. Fig 2 shows the radiant points of meteors observed by the Sharjah and Al-Yahar towers during the period between May 2019 and April 2020. On the map, constellations such Orionids and Taurids are denoted as J5_Orio, J5_nTa and sTa, respectively. Hence, the radiant points that are close to a constellation imply that they belong to the respective meteor group. In this figure, there are meteors that belong to the Orionids meteor shower, as well as Southern and Northern Taurids and several others, in addition to sporadic meteors that do not belong to any shower. By locating the radiant maps, the network ensures its accuracy in terms of linking a meteor to its respective shower. The radiant velocity is color coded as shown in the figure."

Following figure shows selected ionograms obtained during a 24-hour period from LT 4:00 (UT 0:00) on July 31, 2019 to LT 4:00 on August 1, 2019. It can be observed that Es layer traces are present persistently over the 24-hour period. Most of the traces indicate an f-type (flat) Es layer, however, c-type Es layers are also seen infrequently.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Frequency (MHz)

Reviewer 1

6. Lines: 109-110: Haldoupis et al. (2007) only talk that the Es layers and the meteoric influx follow a similar seasonal dependence marked by a strong summer maximum only. The phrase seems that the results of Haldoupis et al. (2007) are related with both solstices.

Authors' Response

In the para mentioned by the reviewer (Lines: 109-110), authors have mentioned that there are numerous studies showing that the meteor count rate peaks in summer which was not observed by the data collected for this study. Haldoupis et al. (2007) showed the same by using radio frequency radar data from the mid-latitudes. In addition, in Fig. 2 of their article, Haldoupis et al. (2007) clearly showed that there is also a good correlation present between mean daily foEs and meteor counts throughout the year; in all four seasons.

Reviewer 1

7. The authors mentions that the "There are also numerous studies whose results are inconclusive", but they do not perform a deeply discussion about to works.

Authors' Response

Authors are thankful for the reviewer for pointing out the missing information. Following lines has been added in the manuscript for references:

"For example, Baggaley and Steel (1984) were not able to find any correlation between meteor activity and occurrence of Es layers. Kotadia and Jani (1967) reported that they did not find any increase in the occurrence of Es layers during a period of anomalously large increase in meteor incidence in 1963, but instead found that Es layers were formed less frequently during that period, suggesting an inverse relationship between the formation of Es layers or meteor incidents. The results presented in this paper also follow a similar pattern, with foEs decreasing significantly during the period between October 2019 to January 2020; even with the increased meteor count during that period (see Fig. 4)."

Baggaley, W. J., & Steel, D. I. (1984). The seasonal structure of ionosonde Es parameters and meteoroid deposition rates. Planetary and Space Science, 32(12), 1533–1539. doi:10.1016/0032-0633(84)90021-7.

Kotadia, K. M., & Jani, K. G. (1967). Sporadic-E ionization and anomalous increase in the rate of radar meteor counts during 1963. Journal of Atmospheric and Terrestrial Physics, 29(2), 221–223. doi:10.1016/0021-9169(67)90137-7.

Reviewer 1

8. Figure 5 should be in discussions instead of conclusions.

Authors' Response

Authors would like to thank reviewer for pointing this out. The manuscript has been thoroughly read by the authors and the language mistakes have been rectified, wherever possible.

Reviewer 1

9. Lines 157-159: The authors could give more proposals because this behavior occurs over the analyzed region.

Authors' Response

Following sentences have been added considering reviewer's comments:

"This may have happened because plasma density abnormalities may exist which may cause ionograms to record scatter echoes beyond the foEs. The abnormalities are caused by plasma instabilities due to the various electrodynamic processes in the ionosphere. Meteoric activity may provide metallic ions to the ionosphere, but they may not be displayed in ionograms if the conditions are unfavorable. This may be why a good correlation between meteor activity and Es layer is not seen by our two collocated instruments. Such results have been rarely reported in the literature and do not comply with frequently reported studies which established a strong seasonal correlation between daily meteor counts with daily averages of Es layer occurrences, as mentioned in the references above."

Reviewer 1

10. Do the authors only consider the nighttime values of foEs to perform the correlation in Figure 5? Does this anti-correlation in this Figure not occur because the Es layer is very dynamic?

Authors' Response

Both full day and nighttime foEs values are used to perform correlation analysis presented in Fig 5. We have presented both data sets. As shown in Fig 5, the red line (and dots) indicates the correlation pattern (individual relationships) of the temporal occurrences of foEs with respect to the meteor count. Since presence of Es layer is a daytime phenomenon, the relationship of the full day foEs averages and the meteor count would be considered as a legitimate comparison. However, pattern of nighttime foEs averages and the meteor count data (which is actually observed during nighttime) shows almost the similar relationship confirming the consistency of the results (blue line and dots in Fig 5).

Authors agree with the referee that the daily presence of the Es layer over Arabian Peninsula is very dynamic, however, the anti-correlation behavior presented in Fig 5 is not affected by this fact because the correlation behavior has been calculated using monthly averages which has smoothen out the daily fluctuations (as shown by thick blue/brown curves of monthly averages in Fig 4).

Reviewer 1

11. There are many mistakes in the language (for example, relationship in Figure 5), and the English need to be improved.

Authors' Response

Authors would like to thank reviewer for pointing this out. The manuscript has been thoroughly read by the authors and the language mistakes have been rectified, wherever possible.

Reviewer 1

12. Please, consider including the word layer after the Es.

Authors' Response

The word layer has been included after Es in the revised manuscript (highlighted in red).

Reviewer 2

The paper presents a topic of sure interest that can stimulate the curiosity of a number of scientists because it poses questions still unsolved and because the analysis is based on measurements taken in a region scarcely reported in the open literature. This is the reason why I would be in favour of the paper publication.

Authors' Response

Authors would like to thank reviewer for spending his/her precious time to read and comment on the paper. The comments from the reviewer have certainly helped improve the quality of the paper.

Reviewer 2

Nevertheless, my major concern is about the Es definition: are the authors considering the foEs or the appearance of Es? I see some confusion in the manuscript between the two quantities and I wonder why the authors are accounting for foEs instead of focusing on the occurrence of Es.

Authors' Response

In this work, the foEs has been used as an indicator of the intensity of the presence of Es over the observed region. Authors had considered comparing individual events of Es with the presence of meteor counts but could not find a scientific way to do so since the meteor counts are done only during nighttime because of visual camera observations. At the other end, the Es is mostly present in the daytime hours and recorded through ionograms every 15 minutes.

In order to compare the nighttime meteor count to the day/nighttime Es occurrences, it is understood that average daily Es intensity and daily meteor count would be appropriate measures to compare the trends of the number of meteors present and their impact on the presence of Es. This is not the first time that the comparison has been done in this way. Other authors (such as Haldoupis et al., 2007) have also used the same strategy to compare the two independent data sets for analysis.

In order to make it clear for the reader, following sentence has been added at the end of 'Data and Methodology' section (highlighted in red in the revised manuscript):

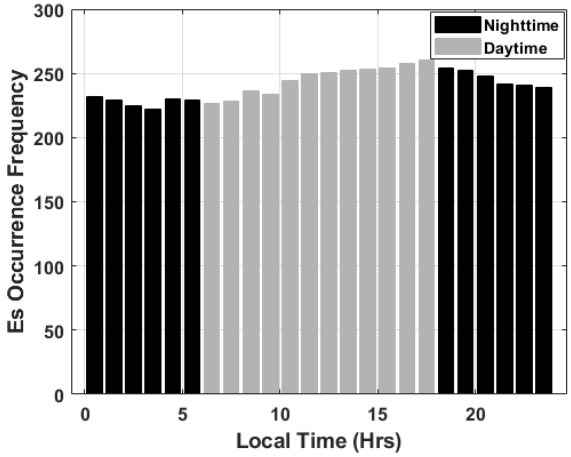
"Since the data from meteor towers are only available from nighttime observations and the data from ionosonde is observed throughout the day and night, the daily Es intensity (average foEs value) has been used to compare with the daily meteor count to study the impact of the number of meteors present and their influence on the presence of Es (Haldoupis et al., 2007)."

Reviewer 2

Here follow some major issues that the authors might consider. In the Discussions: You write "A constant presence of Es can be observed throughout the year and all hours of the day", but the persistence throughout the year is not visible from your plot in which you identify the hourly average foEs as function of the day time. To show such consistency you should include the count.

Authors' Response

As per reviewer's request, the plot shown below has been included as Fig 3(a) in the revised manuscript to show consistent presence of Es occurrences (number of Es events) observed from the ionosonde; throughout the year as function of local time. Figure below clearly shows that a constant presence of Es occurrences can be observed on all hour of the day.



In order to be clear that the intensity of Es (average foEs values) shown in Fig 3(b) (Fig 3(a) in the original manuscript) is much higher around midday hours compared to early morning or evening hours, regardless of the number of Es occurrences. The sentence mentioned by the reviewer in the comment above has been rephrased as follows (highlighted in red in the revised manuscript):

"Fig 3(a) and 3(b) show that a constant presence of Es can be observed throughout the year and all hours of the day with higher intensity (average foEs) around midday hours and with lesser intensity at early morning and nighttime hours".

Reviewer 2

You write "The trend of monthly averages of Es clearly shows a rise in summer months and a decline in the autumn and winter months." From the plot I can see an increase in springtime and a decrease from early summer.

Authors' Response

The intention here was to convey that the trend of Es shows higher values in summer and lower values in winter months. Off course, the in-between transitions occur during in-between seasons of spring and autumn, respectively. However, authors agree with the reviewer that the statement is not stating the idea clearly and needs rephrasing. The rephrased sentence has been included in the revised manuscript as follows:

"The trend of monthly averages of Es layer intensity shows a maximum in late spring and early summer months and a minimum in winter months (except for a slight peak in January)".

Reviewer 2

In figure 5 are you reporting the foEs or the count of Es occurrence?

Authors' Response

Fig 5 is a relationship between Es layer intensity i.e. monthly averages of foEs values. To clarify it, the caption of the figure has been modified with an indication that the Es intensity is actually monthly averages of foEs values (highlighted in red in the revised manuscript).

Reviewer 2

Minor revisions Fig.3 caption: meteor instead of metero Lines 106-110 page 4: replace o with ◦ Line 119 page 4: Fig 4 shows

Authors' Response

Corrected.