Manuscript No.: egusphere-2025-1524

Manuscript Title: Variation characteristics of sporadic-E layer in East Asia based on long-term data

Replies to Reviewer 2's Comments:

This manuscript analyzes the morphology of sporadic E (Es) layers over the Asian region using foEs measurements from 21 ground-based ionosonde stations. While the topic is relevant and the dataset has the potential to contribute to regional Es climatology, the main conclusions presented in the manuscript are not sufficiently supported by rigorous analysis. Substantial revisions would be required before the study could be considered for publication. My detailed comments are provided below.

Reply: Thank you very much for taking the time to review this manuscript and provide valuable feedback. We greatly appreciate the constructive comments and suggestions, which have helped us improve the quality and clarity of our work.

(1) Line 112-117. The paragraph does not clearly explain how the raw foEs data were preprocessed. Key information is missing, including a) the altitude range or criteria used to select valid Es, b) how missing data were identified and removed, c) the total volume of raw data and processed data. Without these details, the reproducibility and reliability of the results cannot be evaluated.

Reply: Thank you for your comments. In this study, the method for selecting valid Es is as follows: the virtual height of the echo must fall within the range of 90 – 140 km, and the trace should exhibit a horizontally thin-layer structure (traces showing parabolic shapes are generally identified as regular E-layer echoes and thus excluded). During data processing, missing data are labeled as “NaN” and automatically excluded from statistical analyses.

The original data have a sampling interval of one hour, yielding 24 foEs values per day. The total amount of raw data for one year is approximately 24×30 (days per month) × 12 (months). After processing, only the monthly median values are retained; thus, the total amount of processed data for one year is reduced to 24×12 (i.e., one median foEs value per hour over 12 months).

(2) Inconsistent use of median vs. mean. The manuscript should justify why the median was chosen instead of the mean or maximum value for characterizing foEs. For example, in Figure 2, the author used "median mean", but it is unclear how it was calculated. In Figure 3, the "annual mean" is used instead of the median. Why do authors need to manually select different metrics？

Reply: Thank you for your comments. We sincerely apologize for the confusion caused by the authors' unclear expressions, which may have hindered the reviewer's understanding of the paper. The foEs dataset selected for this study includes a large number of stations, covers a long time span, and contains a substantial volume of data. To facilitate the investigation of the long-term variation characteristics of foEs over East Asia, we adopted the monthly median at each station as the basic research unit, rather than focusing excessively on data from specific individual days.

During statistical analysis of these monthly medians—such as examining their diurnal variation, seasonal variation, annual variation, and solar cycle variation—it is necessary to take averages of the monthly medians. This has led to situations in the text where median, mean, and even the term "median mean" appear in different places, depending on the specific statistical context.

(3) Line 244-245. The manuscript claims that foEs values during low solar activity are stronger than during high solar activity. However, Figure 8 only displays colorbar without specific values, making the conclusion unverifiable. Before drawing such conclusions, quantitative comparisons, such as the average change or spectral changes, must be made.

Reply: Thank you for your comments. To conduct a quantitative comparison, we selected the years 1999 – 2002 and 2011 – 2014 as representative solar maximum periods (years of high solar activity), and 2006 – 2009 and 2017 – 2020 as solar minimum periods (years of low solar activity). We then compared the overall annual mean foEs values for these periods. The results show that the average foEs during solar minimum years is higher than during solar maximum years, with an increase of approximately 0.1 – 0.3 MHz. The foEs values for representative stations are listed in Table 1.

Table 1 Comparison of the average foEs values between solar maximum years and solar minimum years

Index	Station name	Average foEs value in solar maximum 1999-2002 (MHz)	Average foEs value in solar maximum 2011-2014 (MHz)	Average foEs value in solar minimum 2006-2009 (MHz)	Average foEs value in solar minimum 2017-2020 (MHz)
1	Manzhouli	2.3870	2.7498	2.7278	3.0862
2	Beijing	2.7574	2.7954	2.8460	2.8793
3	Chongqing	3.0522	3.0016	3.0953	3.1690
4	Guangzhou	3.0612	2.9079	3.0062	3.1764
5	Haikou	2.8560	2.7498	2.9502	3.1858

(4) Previous studies have shown that weak foEs (< 3 MHz) are more sensitive to solar cycle modulation (see Figure 6 in Tian et al., 2024. Check https://doi.org/10.1029/2024JH000279). Table 2 in the present manuscript shows

correlations between overall foEs and sunspot number, but it does not distinguish between weak and strong foEs. I encourage the authors to examine the correlations between weak/strong foEs and solar activity. Such an analysis would help clarify whether the solar cycle dependence of Es morphology is driven primarily by weak events, strong events, or both.

Reply: Thank you for your comments. To further analyze the correlations between weak/strong foEs and solar activity, Table 2 presents the calculated occurrence probabilities of weak Es (foEs < 3 MHz) and strong Es (foEs > 5 MHz) during solar maximum periods (1999 – 2002 and 2011 – 2014) and solar minimum periods (2006 – 2009 and 2017 – 2020).

Table 2 Comparison of the occurrence probabilities of weak foEs and strong foEs during years of high and low solar activity

Index	Station name	Occurrence probability (foEs<3MHz) in solar maximum	Occurrence probability (foEs>5MHz) in solar maximum	Occurrence probability (foEs<3MHz) in solar minimum	Occurrence probability (foEs>5MHz) in solar minimum
1	Manzhouli	0.4783	0.0113	0.4284	0.0421
2	Beijing	0.5846	0.0360	0.6102	0.0595
3	Chongqing	0.4566	0.0807	0.4154	0.1181
4	Guangzhou	0.4358	0.0877	0.3364	0.0694
5	Haikou	0.4974	0.0321	0.4488	0.0451
6	Changchun	0.5664	0.0408	0.5204	0.0747
7	Lanzhou	0.4536	0.0703	0.4905	0.0777
8	Lhasa	0.4553	0.0490	0.4271	0.0634
9	Urumchi	0.5781	0.0204	0.5378	0.0425

The results indicate that the occurrence rate of weak Es is slightly higher during solar maximum than during solar minimum, whereas the occurrence rate of strong Es is significantly higher during solar minimum compared to solar maximum. The occurrence rate of weak Es is slightly higher during solar maximum than during solar minimum, which is consistent with the findings of Tian et al.

Penghao Tian, Bingkun Yu, Hailun Ye, Xianghui Xue, Jianfei Wu, Tingdi Chen, Deep Learning Insights Into Ionospheric Sporadic E Irregularities Under Different Solar Activity Conditions, J. Geophys. Res., 2024, 129, e2024JH000279.

(5) Although the manuscript maps the spatiotemporal distribution of foEs, it provides little discussion of the underlying physical mechanisms. For example, why does the nighttime Es intensity center shift northeastward? Without physical interpretation, the results remain descriptive rather than scientific, limiting the manuscript's contribution to the field.

Reply: Thank you for your comments. We have added discussions and analyses of the underlying physical processes and mechanisms in the revised version of the manuscript. Regarding the reason for the northeastward shift of the nighttime Es intensity center, there is currently no definitive conclusion. One possible explanation is that the dominant controlling factors for Es layer formation differ between daytime and nighttime, leading to a shift in the location of the Es intensity center from day to night.

The observed diurnal asymmetries in the intensity of the Es in East Asia may result from variations in the dominant controlling factors of foEs across different periods. During daytime, the electron density of the Es is primarily governed by solar radiation, showing significant latitudinal dependence. However, when solar radiation weakens at night, its controlling effect diminishes, allowing the influence of other factors such as tides and gravity waves to become more pronounced. This may be the cause of the diurnal inconsistency in the Es layer intensity center.

(6) Line 316. One of the main conclusions is that the Es intensity center is located near 30N. However, this conclusion appears to be based solely on the spatial distribution in Figure 2. In the other word, different interpolation methods may lead to different conclusions. To validate this conclusion, satellite observations (e.g., COSMIC-1/2) should be considered. Otherwise, the latitudinal maximum remains uncertain and may be an artifact of the interpolation procedure.
Reply: Thank you very much for the reviewer’s constructive comments. The ionosonde network in East Asia is relatively sparse, with adjacent stations spaced 3 – 6 degrees apart in latitude. As a result, the foEs distribution maps obtained through interpolation may indeed contain certain errors. To further validate the conclusion, we plan to incorporate occultation observation data in future work and conduct comparative validation studies between ionosonde and satellite observations.

Thank you for your great effort and valuable time spent in reviewing this paper. We sincerely wish that with the careful revision of the paper, the revised manuscript is acceptable for publication.