Comments on the manuscript entitled '**Ionospheric Plasma Irregularities During Intense geomagnetic storms of Solar Cycle 25**' authored by Nadia Imtiaz et al. (2025) to ANGEO (manuscript egusphere-2025-86).

General comments:

This study presents the characteristics of equatorial and low latitude ionosphere during four intense geomagnetic storms that occurred on March 23–25, 2023, April 23–25, 2023, November 4–7, 2023 and May 10–13, 2024 in the ascending phase of Solar Cycle 25 based Joule Heating (JH) rates at high latitudes. For this purpose, authors have utilized the Weimer 2005 Model simulations to analyse the JH patterns along with Madrigal TEC maps to identify the changes in the intensity, location, and symmetry of the equatorial ionization anomaly (EIA) during these intense geomagnetic storms. Equatorial/low-latitude ionospheric plasma irregularities at different longitudes under geomagnetically disturbed conditions are studied using the TEC derived ROTI measurements. While a strong JH is observed during the May 2024 storm in the main phase, the other storms have the following order from strong to weak: March 2023, April 2023, and November 2023. The authors have investigated especially the role of asymmetric Joule heating in the structuring of the EIA like double crest, single crest or merged. Authors have utilized these features to investigate the formation or suppression of equatorial plasma irregularities. It is suggested that the generation of these ionospheric plasma irregularities and their latitudinal distribution strongly dependent on EIA's density gradients and latitudinal density structure. For instance, while the double crest EIA structures with strong plasma density gradients playing an important role in the generation of post sunset ionospheric plasma irregularities during the main phases of these four geomagnetic storms, single crest or merged EIA structure didn't favour the generation of ionospheric plasma irregularities. In addition, the role of storm-time penetration electric field in the structuring and seeding of ionospheric plasma irregularities have been investigated. Analysis of these storms by authors suggest that solar wind parameters, geomagnetic activity, JH, and PPEFs significantly influence ionospheric TEC variations, EIA crest formations, and post-sunset plasma irregularities. These investigations revealed that these storms highlighted the importance of inter-hemispheric asymmetries in JH that affected the distribution and magnitude of ionospheric irregularities. Finally, the paper concludes that the resulting change in the thermospheric winds and electric fields due to storm conditions can alter the EIA structures which will impact the plasma irregularities at equatorial and low latitudes.

While many of the results presented here are already reported, I believe discussions like role of single EIA, double or Merged EIA on plasma irregularities looks to be interesting though it is known that asymmetry of EIA can suppress the plasma bubbles due to thermospheric meridional winds. I am providing the comments to the authors. The manuscript may be considered for publication only after implementing the comments made in this review report by incorporating appropriate changes.

Specific comments

- It is mentioned that JH is strong in May 2024 Mother's Day storm during main phase. Then it followed like this: March 2023>April 2023>November 2023. Cause of variation proposed: Change in thermosphere winds and electric fields due to storm conditions alter EIA structures. What is the role of thermospheric neutral density such as O/N2 ratio on the EIA single crest, double crests?
- Whether authors have investigated positive/negative storms on the plasma irregularities
- How the symmetry/asymmetry of EIA with single, double crests can influence the EPBs are not discussed. Please provide discussions.
- What is the role of electric fields on the generation/suppression of plasma irregularities?
- Why authors have chosen TEC maps between 18:00-00:00 UT for all the storm events in Figure-6? Since different storms have main phases at different UT times, why authors have chosen this time interval to study the plasma irregularities and their connection to EIA.

- The plots shown in Figure-6 can be plotted as a line plots to show clear asymmetry in EIA. Also in the plot, map for 23:00 UT is not shown. Whether it is plotted like this only, please clarify.
- Role of geomagnetic storms on plasma irregularities in the following papers: S. Sripathi and Ram Singh, A study on the response of the ionosphere to the three major space weather events of 2015 using meridional chain of ionosondes and GPS receivers over India**,** journal of Sun and Geosphere**,** DOI: 10.31401/SunGeo.2018.02.08, 2020
- Similarly, the following paper discusses the role of geomagnetic storms and role of Es layers on the plasma irregularities. Please go through it. Singh, R., & Sripathi, S. (2020). A statistical study on the local time dependence of equatorial spread *F* (ESF) irregularities and their relation to low-latitude Es layers under geomagnetic storms. *Journal of Geophysical Research: Space Physics*, *125*, e2019JA027212. https://doi.org/10.1029/2019JA027212
- It is said that the generation of ionospheric plasma irregularities and geographical distribution strongly dependent on EIA density gradients and general density structure. Please include the physics of their dependency.
- It is mentioned that the storm-time Joule heating in high-latitude can cause atmospheric gravity waves (AGWs) to move equatorward, thus providing favourable conditions for formation equatorial/low-latitude ionospheric plasma irregularities. But it is under recovery phase mostly. But here authors are describing plasma irregularities in the main phase. Please clarify.
- Double crest EIA structures with strong plasma density gradient play an important role in generation of post sunset plasma irregularities. Single crest or merged EIA does not favour the generation of irregularity. Please provide brief explanation for this. How the plasma irregularity generation is associated with EIA crest need to be mentioned clearly in the manuscript.
- 3.3.1 Structure of Equatorial Ionization Anomaly (EIA): “This merging and subsequent increase in TEC were driven by enhanced JH and geomagnetic activity”. The claim can be elaborated by explaining the variation of JH with EIA structure.
- In general, PPEFs will affect the equatorial and low latitudes in the main phase of the storm, while Joule heating will affect the equatorial and low latitudes in the recovery phase of the storm through thermospheric wind circulation. However, here, authors are discussing the role of Joule heating during Main phase which I am not able to understand. Please clarify how the Joule Heating can impact the EIA crest in the main phase.
- The EIA trends are visually explained in table-3 with JH values where pattern can be observed. However, there is no mention of physics of their connection with the JH. What is the relation between JH and EIA dynamics are not clearly mentioned. Please explain. Similarly, Table-3 doesn’t show any location where EIA crest is strong/weak. It has to be clearly mentioned.
- 3.3.2 Ionospheric Plasma Irregularities: The observations presented here under PPEFs and DDEFs and claims to have plasma irregularities. The proof/data/evidence/observation of the irregularities are needed to be included.
- What is the role of atmospheric waves and tides on the variability of the PRE, EIA and plasma irregularities. It is known that equatorial electrodynamics plays significant role in day-to-day variability of the E X B drift and RT instability triggered plasma irregularities. So, this point needs to be addressed.
- Authors have chosen these four storms without looking into the role of seasons on the EIA. Usually, it is standard practice to choose storms that fall in equinox. Please address this point.
- If you want to study only 18:00-00:00 UT, please show this period with yellow highlight in the Figures-1-4 so that it is easy for the readers to follow it. Currently, authors have highlighted the main phase of the storm with ‘red’ rectangle box. In fact, in these figures, AE/AU/AL is missing.
- In the introduction, the sentence starts with ‘Ionospheric effects on applications are generally minor in mid-latitudes…’ may be replaced with ‘Ionospheric effects are generally minor in mid-latitudes…’ as the sentence is not conveying message correctly.

- "It is generally said that during storm time, it increases the daytime eastward electric field". $E_{total}(t)=E_{quiet}(t)+E_{PPEF}(t)$. It can either increase or decrease the equatorial zonal electric field, depending on IMF Bz polarity and whether you are on the dayside or nightside. This equation can be included.
- Correct 'Disturbed Dynamo (DD)' to 'Disturbance Dynamo (DD)'