

Response to the Reviewer's Comments

Manuscript title: Nocturnal variability of total electron content (TEC) at Koudougou (Burkina Faso) during three geomagnetic storms of solar cycle 24 : implications for equatorial ionospheric irregularities

1. Introduction

We thank the reviewer sincerely for the time and effort devoted to evaluating our manuscript. The comments were precise, constructive, and have led us to substantially improve both the physical interpretation and the overall quality of the work. We address each point in detail below.

2. Physical interpretation of positive and negative TEC phases (lines 100–104)

Reviewer's comment : The interpretation linking positive TEC phases to PPEF and negative phases to the disturbance dynamo is oversimplified. The manuscript does not explain how disturbed electric fields alter the TEC.

Our response: We fully agree. Looking back at our original wording, we recognize that it gave the misleading impression that the sign of the TEC perturbation could be directly and uniquely assigned to a single mechanism, which is of course not the case. We have corrected this in the revised manuscript by removing the original statement and adding a dedicated subsection (Section 2.7: *Electrodynamic mechanisms and TEC response during geomagnetic storms*) that walks through the complete physical chain linking IMF Bz variations to TEC changes.

In this new section, we explain that a rapid southward turning of IMF Bz can produce an undershielding PPEF directed westward at nighttime, driving a downward $E \times B$ drift and a negative TEC response (Fejer and Scherliess, 1997); that an abrupt northward turning following a sustained southward interval may generate an overshielding PPEF directed eastward at nighttime, producing an upward drift and a positive TEC response (Kelley et al., 1979); and that the disturbance dynamo electric field, which also produces an eastward nocturnal field but develops more gradually and persists for up to 30 hours, constitutes a distinct and longer-lived perturbation (Scherliess and Fejer, 1997; Fejer and Scherliess, 1995).

For each of the three storms, we have revisited the temporal evolution of IMF Bz and rewritten the discussion to link the observed TEC phases to these specific mechanisms, while being careful to present these as physically consistent interpretations rather than directly demonstrated processes, given that no direct electric field measurements are available at the station.

3. Interpretation of the σ_{TEC} increase during J+1 (lines 160–164)

Reviewer's comment : The explanation invoking a return of the ascending $E \times B$ drift during J+1 is not supported by the IMF Bz data, which remains persistently negative throughout the recovery phase with no abrupt variation.

Our response: The reviewer is right, and we appreciate the precision of this observation. We went back to the IMF Bz time series for the 14 July 2012 storm and confirmed that Bz indeed stays negative throughout the recovery phase without any abrupt northward turning that could support a PPEF-driven ascending $E \times B$ drift. The original explanation was therefore physically unjustified and has been removed.

In the revised manuscript, we now attribute the elevated σ_{TEC} of 5.863 TECU during J+1 to the sustained action of the disturbance dynamo, which develops progressively as thermospheric winds propagate equatorward following auroral heating and can remain active for up to 30 hours after storm onset (Fejer et al., 1983; Scherliess and Fejer, 1997). This interpretation is consistent with the observed Bz behavior. We also acknowledge explicitly that, without direct measurements of ionospheric electric fields or neutral winds at Koudougou, this remains a physically motivated interpretation rather than a directly demonstrated mechanism.

4. Superposed Epoch Analysis (SEA)

Reviewer's comment : The SEA technique is not well suited to this type of data given the strong dependence of storm-time electric field effects on local time of onset, storm duration, and substorm occurrence. The reviewer recommends suppressing this part but retaining panel (b) of Figure 6.

Our response: We thank the reviewer for this methodological point and agree with the reasoning. The ionospheric response to geomagnetic storms is indeed too event-specific for temporal alignment to be physically meaningful across only three events with very different characteristics. The SEA section has accordingly been removed from the revised manuscript.

Panel (b) of Figure 6 has been retained, as it provides a useful side-by-side comparison of σ_{TEC} values across the three storms and all storm phases without implying any temporal equivalence in the electrodynamic processes.

5. Fejer et al. (2008) and direction of the disturbance dynamo electric field (lines 200–202)

Reviewer's comment : The reference to Fejer et al. (2008) is inappropriate in this context, as that paper deals exclusively with quiet-time plasma drifts. Furthermore, the nighttime disturbance dynamo generates an eastward electric field, not westward as stated.

Our response: Both points are well taken. The citation of Fejer et al. (2008) in the storm-time discussion was indeed a contextual mismatch as that paper models quiet-time equatorial vertical drifts and has no bearing on storm-time electrodynamics. It has been removed from that context. As for the direction of the DDEF, we acknowledge the error: the disturbance dynamo generates an eastward electric field at nighttime, as established by Scherliess and Fejer (1997) and Blanc and Richmond (1980). This has been corrected consistently throughout the revised manuscript.

6. Bibliographic accuracy (line 204)

Reviewer's comment : Tulasi Ram et al. (2014) is not in the reference list. The paper found was published in 2009 and deals with a different subject. These two examples raise concerns about bibliographic accuracy.

Our response: We sincerely apologize for these bibliographic inaccuracies. We have carried out a thorough verification of every reference in the manuscript against its original published source, and corrected all errors identified.

Regarding the specific case raised by the reviewer, the paper listed as Tulasi Ram et al. (2014) was in fact published in 2009. The correct citation is:

Tulasi Ram, S., Su, S.-Y., and Liu, C. H.: FORMOSAT-3/COSMIC observations of seasonal and longitudinal variations of equatorial ionization anomaly and its interhemispheric asymmetry during the solar minimum period, *J. Geophys. Res.*, 114, A06311, doi:10.1029/2008JA013880, 2009.

Furthermore, this reference was cited in a context unrelated to its actual content and has been replaced in the revised manuscript by references that are directly relevant to the discussion of storm-time ionospheric electrodynamics.

More broadly, our review of the full reference list revealed that six references were cited in the text but missing from the list. These have now been added: Kelley et al. (1979), Fejer et al. (1983), Fejer and Scherliess (1995), Fejer and Scherliess (1997), Gonzalez and Tsurutani (1987), and Abdu (2016). We are confident that the revised reference list is now complete and accurate.

7. Figure resolution and language

Reviewer's comment : The resolution of the figures is insufficient and some text inside them is unreadable. The text on figures should be in English.

Our response: All figures have been entirely redrawn from scratch. The revised figures are exported at 300 DPI, with font sizes increased to a minimum of 11 pt for annotations and 13–14 pt for axis labels and panel identifiers. Every text element previously written in French has been translated into English. Legends have been repositioned outside the plotted curves to eliminate overlap with the data. To further improve readability, each storm figure has been divided into two separate panels : one grouping the solar wind and geomagnetic parameters (panels a, b, c) and other grouping the ionospheric parameters (panels d, e, f) , allowing larger individual panel sizes at publication quality.

8. Consistency between dip angle and magnetic latitude (lines 60 and 64)

Reviewer's comment: Please check the consistency between the dip and magnetic latitude values on lines 60 and 64.

Our response: We thank the reviewer for catching this inconsistency. The dip angle of $+8.24^\circ$ is the instrumental value directly measured at the Koudougou SCINDA GPS station and is the correct reference. Applying the standard relation $\tan(I) = 2 \times \tan(\lambda_m)$, where I is the dip angle and λ_m the magnetic dip latitude, gives a magnetic latitude of approximately 4.1°N . The previously stated value of $\sim 2^\circ\text{N}$ was erroneous and has been corrected to 4.1°N throughout the revised manuscript. This places Koudougou close to the foot of the northern crest of the equatorial ionisation anomaly, which is physically consistent with the ionospheric behavior described in the paper.

Conclusion

We hope that the revised manuscript satisfactorily addresses all the reviewer's concerns. We remain available to provide any further clarifications that may be needed.

Thanks a lot again for allowing us to grow more in this field through your corrections and suggestions