Responses to the Comment and/or Suggestions from Anonymous Referee #2

Manuscript: angeo-2021-71
Title: Study of the equatorial and low-latitude TEC response to plasma bubbles during the solar cycle 24-25 over the Brazilian region using a Disturbance Ionosphere indeX
Authors: Picanço et al.
Reviewer: Anonymous Referee #2

Comments on the manuscript entitled "Study of the equatorial and low-latitude TEC response to plasma bubbles during the solar cycle 24-25 over the Brazilian region using a Disturbance Ionosphere indeX" by Picanço et al. submitted to the Annales Geophysicae journal.

The authors use Disturbance Ionosphere index (DIX) to evaluate the ionospheric responses to Equatorial Plasma Bubbles (EPBs) between 2013 and 2020 over the Brazilian sector. The results of the DIX were compared concurrent EPB observations from ionosonde and All-Sky Imager data. The authors show that the DIX was able to detect EPB-related disturbances both in terms of intensity and occurrence times. Finally, it was shown that the magnitude of the disturbances depends on solar activity. The major points of this study are quite interesting and useful. However, there are some comments that the authors need to consider to strengthen the points presented in this work. Please find the comments below.

Our response:

We would like to thank Reviewer #2 for his/her time spent evaluating our paper. In the following lines, we provide the specific answers to each point raised by the reviewer. We included the information in the revised version of the paper as suggested by the reviewer.

Line 89: There is the need to state the basis for selecting the EPBs under this study in the section 2, or are these the only EPB events between 2013 and 2020.

Our response:

We thank the reviewer for highlighting this point. We will include all information in the revised version of the paper as suggested by the reviewer. We selected EPB events that occurred near the summer of each year, aiming for a better comparison among them. In this regard, we also based our selection on data availability, taking into account the simultaneity of GNSS, Ionosonde, and All-Sky Imager observations. We included these details in the revised version of the paper as suggested by the reviewer.

Line 97: There is no TEC_k in equation (1), the authors should revise this equation.

Our response:

We thank Reviewer #2 for the relevant observation. We corrected that in the revised version of the paper.

The new equation is:

$$DIX_k(t) = \left|\frac{\alpha\left(\Delta TEC_k(t)/TEC_k^{Qd}(t)\right) + \Delta TEC_k(t)}{\beta}\right|, \qquad (1)$$

Line 115: It may be useful to have a third column on Table 1 describing the implication of column 2.

Our response:

We thank Reviewer #2 for such a pertinent suggestion. However, we comprehend that this knowledge goes beyond the scope of the present paper. On the other hand, such a suggestion is relevant for evaluating DIX applications within a space weather context. Therefore, it surely will be put into practice in our future manuscript since it is possible to compare GNSS positioning errors with the DIX scale. In the present work, we have normalized the ionospheric disturbances into a scale ranging from 0 to 5, considering the level 5 as the highest disturbed state observed in all analyzed cases.

Line 252-254: ''Such effect can be explained by the presence of the Equatorial Ionization Anomaly (EIA) southern crest, which produces a large amount of plasma in this region, making the TEC percentage changes also higher'' …. Did the authors confirm this inference from the TEC observations since some other cases did not follow this inference?

Our response:

We thank Reviewer #2 for raising this point. The equatorial ionization anomaly (EIA) is mainly characterized by a plasma trough in the equatorial region, which is flanked by two crests in low latitudes, generally occurring at around ±15° dip latitude. The EIA crests present a high day-to-day variability, which can suddenly change its position (Takahashi et al., 2016). Since we are using data from four nearby GNSS stations at low latitudes, the EIA south crest might be above or below those stations over time. In some cases, DIX values at low latitudes might be higher than those over the magnetic equator, considering that these stations are under influence of the southern EIA crest and can be affected by its dynamics. We included this explanation in the text to clarify to the reader.

Takahashi, H., Wrasse, C. M., Denardini, C. M., Pádua, M. B., de Paula, E. R., Costa, S. M. A., et al. (2016). Ionospheric TEC weather map over south America. Space Weather, 14, 937–949. https://doi.org/10.1002/2016SW001474.

Line 237-239: The reason for the selection of the specific ASI snapshots and the ionograms under Figures 4 & 5 should be mentioned.

Our response:

We thank the reviewer for pointing this out. We selected snapshots that could facilitate the visibility of the plasma bubble signatures. In this regard, ASI images can be affected by other atmospheric phenomena (eg clouds, rain), and the spread-F observed in the ionograms tends to be more intense at the peak of the bubble passage over the ionosonde field of view. We considered those factors when selecting the images. We included more details about the referred data selection in the revised version of the paper.

Line 237: There is the need for the authors to state the possible reason(s) why at times the response of the DIX is simultaneously observed at both the equatorial and low latitude stations while it's not at other times, does the authors have any explanation for this?

Our response:

We thank Reviewer #2 for raising such a relevant point. We agree with the observation that in some EPB cases the DIX responses are not observed simultaneously at equatorial and low-latitude GNSS stations.

In this context, we start arguing from the concepts presented in the previous question, which deals with the intensity of plasma depletions in different latitude ranges. If we take the case presented in Figure 4.d as an example, we notice that the bubble signature did not fully reach the field of view of the Cachoeira Paulista All-Sky Imager. As a consequence of this scenario, DIX values at low-latitude stations remained lower since only partial plasma bubble signatures have reached this region in comparison to the equatorial ones. Moreover, the opposite situation does not occur, as we did not detect cases in which DIX peaks associated with EPBs were detected only over low-latitude GNSS stations.

Therefore, those cases where DIX peaks are not observed simultaneously over equatorial and low-latitudes stations are possibly due to EPB events that have not fully developed to the low-latitude ionospheric region.

All this information was included in the new version of the manuscript.

Line 355: Change '6 January 2015' to 6 January 2018.

Our response:

We apologize for that. We have corrected it.

Line 394: It is not quite clear what the authors meant by '… while the ionosphere over low latitudes behaved similarly ...' This is with respect to what?

Our response:

We apologize for that little mistake. We have corrected it as follows.

"It is noteworthy that the DIX over the equatorial GNSS stations presented a pulse-like response in the presence of plasma bubbles/spread-F, while the ionosphere over low latitudes behaved similarly to the expected for non-disturbed periods, without the concurrent DIX response since no spread-F was registered."

Line 415: For the presentation in Figure 6, it will be better to include more EPB events between 2013 and 2020 if there are, for more reliable statistics. The authors can also show the error bars of the standard deviation for each year.

Our response:

We thank reviewer #2 for his/her suggestion. We included more information in the graph as suggested.

Line 446: change 'those results' to 'these results'.
Our response:
We have corrected it. Thank you.

Line 454-455: Can the authors expound on how they arrived at this conclusion: '*Finally, this feature can be directly associated with the physical mechanisms that control the production of electron-ion pairs in the ionosphere*'.
Our response:
We thank the reviewer for raising this point. We have removed such unnecessary sentences.
Line 474: The authors can mention the specific event being referred to here.
Our response:
We have included the information as the reviewer suggested (see below). Thank you.

"We observed a delay in the DIX response time to EPBs between low-latitude and equatorial GNSS stations in some of the studied cases (2013, 2014, and 2016). For instance, this time delay was 40 minutes during the first case (2013). Therefore, we suggest it as the latitudinal propagation time of the EPB-related plasma disturbances between equatorial and low-latitude regions, which is a new feature observed using DIX. Therefore, the DIX can estimate the propagation time of the EPB-related ionospheric disturbances between latitude ranges."

Line 484: Change '*The contribution of neutral atmospheric effects intensified some DIX disturbances observed during the EPB periods*' to '*The contribution of neutral atmospheric effects may have intensified some DIX disturbances observed during the EPB periods*'.
Our response:
We have modified that. Thank you.

The authors did not provide full information of some of references, consider adding the issue and volume numbers to them: line 534, line 541, line 558, line 562, line 566, line 580.
Our response:
This part of the manuscript is now properly updated.

Finally, we would like to take this opportunity to thank the reviewer for kindly evaluating our paper and helping to improve its quality.