Response to Reviewer 3

The Authors deeply appreciate your review. It was constructive and allowed us to improve our work. The Authors have addressed all the Reviewer's doubts, comments and suggestions.

Once the reviewing process finish and, if the manuscript is accepted to publication, the Authors would like to thank you by directly naming you in our manuscript's Acknowledgments statement. We hope the Reviewer does not have issues with that.

We believe that this new version of our manuscript addresses all the Reviewers' comments and solve concerns about our work. Now we proceed to answer your comments and present in detail the way in which we addressed each of the points made by the Reviewer.

Major concern:

Introduction: Needs improvement.

Author's Response:
We appreciate the Reviewer's recommendation. We conducted a revision of the whole Introduction in our manuscript and re-wrote most of it. We put special attention on the writing style in order to give the reader a better understanding of the concepts and motivations behind our work.

We expect that the new Introduction fulfill the Reviewer expectations.

How the regional space weather studies contribute to the global space weather studies?

Author's Response:
In general terms, regional space weather studies have two main purposes: 1) search for the differences between the regional and planetary responses, if there are any; and departing from these differences, 2) address the local affectations/risks of space weather, given the regional distribution of infrastructure/facilities and local services demand. Thus, regional space weather studies give a local understanding of a global phenomena by emphasizing the effects of local conditions.

In addition, regional space weather studies allow to contextualize/address and differentiate risk conditions from space weather phenomena for different regions and societies. This topic is particularly relevant for operative purposes (space-weather services) and governmental management of space-weather risks. Because these regional space weather studies show that each single event would manifest in a particular way, affecting each region in a singular way. Thus, regional space-weather studies like ours show that space-weather manifestations may drastically variate from one region to another. In consequence, in order to address the regional effects of space-weather, it is necessary to carry out studies from a regional approach, complemented by the planetary context.

We think that the new version of "Introduction" make clear all the ideas listed in the previous paragraph. In addition, we modified the last paragraph of our "Concluding remarks".

In the previous version of the manuscript it read:

“Finally, in this work we focus on regional space weather. We identified evidence of regional geomagnetic response that is significantly different from its planetary counterpart. We investigated Ddyn and DP 2 ionospheric currents as the mechanisms for such a regional response. As a result, we were able to isolate the magnetic perturbations associated with those ionospheric currents. The combination of these perturbations with planetary response could approximate the regional geomagnetic response.”

Now it reads:

“*Thus, our study shows that regional space-weather manifestations at central Mexico may significantly deviate from the planetary response. In consequence, in order to address the regional effects of, and risks due to, space-weather in Central Mexico, it is necessary to carry out studies from a regional approach, complemented with the planetary context. Our results highlight the particularities that geomagnetic response has for a given location. Hence, in order to achieve a better understanding of space weather and to improve the operational response, our results evidence for the necessity to include more registers (magnetometers) into the computing of geomagnetic indices, whether planetary or regional.*

Hence, according to our results, during intense geomagnetic storms, in central Mexico, the effects of $Ddyn$ and $DP2$ may induce alterations in the F region of the ionosphere and displace the equatorial ionospheric anomaly towards central and southern regions of Mexico \citep[as showed by] []{dramaria_13}. Therefore we could expect these phenomena lead to ionospheric scintillation, which degrades satellite communications, as well as the precision of navigation and positioning systems, among other services. All these effects can potentially be addressed through local perturbations of the TEC during geomagnetic storm periods (refer to panels (e) of Figure \ref{fig:iono_resp}).
It is important to remark that the surface of Mexico is near 2 million ${\rm km}^2$. This fact made of our results valid only for the central region of Mexico (few thousands of ${\rm km}^2$), leaving the rest of its surface to address. In addition, Mexico is located at North America, and the ionospheric currents pass through and evolve along the whole American continent. Hence, on one hand, it is required more sources of geomagnetic registers in Mexico and, on the other hand, it is necessary to contextualize the geomagnetic response of Mexico with those present in Northern and Central America, and even South America. For the first case, LANCE is developing a the Network of Geomagnetic Stations Mexico (REGMEX) \citep[see][]{corona2024}, to monitoring regional geomagnetic response all over Mexico. Whereas, for the case of contextualize the geomagnetic response of Mexico, this is our immediate future work.”

Also, how is this study related to other studies carried out in the American sector?

Author's Response:
It is important to remark that American continent extends from the north, crossing over the equator, and ending up near to the very south of our globe. Besides, American continent also covers multiple time zones. And since the systems of ionospheric and magnetospheric currents variate with geomagnetic latitude, and the time sector, the ionospheric phenomena and geomagnetic response are likely to be different across the whole American continent. Hence, each hypothetical study performed in different American regions would likely arrive to different results, even if those studies apply similar approaches. Thus, such hypothetical studies would be complementary each other; in such a case, the

more studies in the American sector, the better understanding we will have about the continental geomagnetic response.

In the particular case of our study, we must to recall that Mexico has almost 2 million km^2 of surface; and our study focused in central region of Mexico. Thus, for practical ends, our geomagnetic/ionospheric registers are locate in the center of a square of 1000 km each side, i.e. our registers have, at least, 500 km of missing/complementary data around them. Such a lack of complementary data from other regions of Mexico is mostly due to the absence of geomagnetic registers, because for the studied period, there was only one single geomagnetic data source operating in Mexico, the Magnetic Observatory of Teoloyucan. It is clear, due to the size of Mexico's surface, that the studies that could be directly related with ours would come from the northern, southern, eastern and western regions of Mexico. Sadly, these ideal cases were not available.

In addition, it is important to comment that, in the knowledge of the Authors, regional space-weather studies are scarce for the case of Latin America (from Mexico and south), with the exception of Brazil, and recently Chile and Argentina. These circumstances have two immediate consequences: The first, it is complicated to relate our study with others due to the limited number of studies. And second, tray to relate our work with similar studies made for South American region is not possible due to differences between the geomagnetic and geographic contexts. In a similar manner, we could relate our study with those performed for USA and Canada. Nevertheless such an effort would be purely qualitative because of the geographic gap between the study regions. In addition, besides to be a qualitative enrichment, such an enrichment will hardly affect the results of our work, because our work's purposes were: (1) to isolate the regional geomagnetic response and (2) identify its possible sources; purposes that were fulfilled. In consequence, the regional geomagnetic responses on USA and Canada are not of relevance for our for our work's objectives and compare our work with those kind of studies is also beyond the scope of our work.

We expect that the Reviewer agree with us after the given explanation.

However, we appreciate the Reviewer's comment, we try to include the Reviewer's critics into this point in our work's Concluding remarks. The last paragraph now reads:

"It is important to remark that the surface of Mexico is near 2 million ${\rm km}^2$. This fact made of our results valid only for the central region of Mexico (few thousands of ${\rm km}^2$), leaving the rest of its surface to address. In addition, Mexico is located at North America, and the ionospheric currents pass through and evolve along the whole American continent. Hence, on one hand, it is required more sources of geomagnetic registers in Mexico and, on the other hand, it is necessary to contextualize the geomagnetic response of Mexico with those present in Northern and Central America, and even South America. For the first case, LANCE is developing a the Network of Geomagnetic Stations Mexico (REGMEX) \citep[see][]{corona2024}, to monitoring regional geomagnetic response all over Mexico. Whereas, for the case of contextualize the geomagnetic response of Mexico, this is our immediate future work."

The paper needs to be improved. It is important to add some extra data from Central America and the southern part of the USA. Despite the paper being related to regional response to

geomagnetic storms. Since nowadays there is data available from Central America and the southern part of the USA, It is important to discuss the longitudinal and latitudinal similarities and differences of the regional region.

Author's Response:

The Authors understand the Reviewer's recommendation and fully agree that the inclusion of complementary data would lead to a significant enrichment of our results. However, there are some points that should be taken into account:

1. As it is commented in our manuscript [p. 2, left column lines 58-62 and right column line 3], the scope of our work is to investigate the regional (at central Mexico) geomagnetic response and its possible ionospheric sources. Due to we were able to achieve the manuscript objectives, the additional data from other regions would be complementary, but not necessary for our manuscript's purposes. In addition, due to the size of Mexico's surface, the ideal complementary geomagnetic data would be registered in the north/south and east/west regions of Mexico, as we commented on before. Nevertheless, there were not geomagnetic registers available from those Mexican regions for the studied events.

2. Our analysis required data from geomagnetic field (geomagnetic registers) and Earth's ionosphere (the regional total content of electrons (TEC)). Hence, although there could be complementary sources of geomagnetic data in North-America and potentially in Central-America, in addition to them, we also would require the corresponding TEC data from all those locations. In our experience, to fulfill both conditions is unlikely.

If the Reviewer knows public and open sources that simultaneously offer geomagnetic registers and TEC-data, the Authors would appreciate the Reviewer to share those sources.

3. We agree that is relevant to discuss the differences and similarities not only for north and central America, but for all the American continent. Nevertheless, regarding the Authors' opinion, to compare the geomagnetic response between different geographic regions in American continent is a work with well differentiated purposes from the one is being reviewed, that solely focus in the geomagnetic response at central Mexico and its possible ionospheric sources/causes.

4. Additionally, the latitudinal and longitudinal exploration that the Reviewer suggests is one of our present works. Actually, at this moment we are processing geomagnetic data available through out INTERMAGNET site from sources that share similar geomagnetic latitudes/longitudes to those of central Mexico. Clearly, this comparison will lack of ionospheric data/results and will be part of another independent, but related/complementary, work.

Therefore, although we agree with the Reviewer's suggestion, due to what was discussed in the previous four points, we hope that the Reviewer will be convinced that such a suggestion is outside the scope and purposes of our work. And, although additional data may undoubtedly enrich our manuscript, we chose to keep our text simple, and its extension short, for the sake of maintain the Reader's attention over our analysis and results. However, for the Authors it is important to highlight that we are currently carrying out the work recommended by the Reviewer. Of course, this work is an independent work from the one being reviewed.

In order to include and solve the Reviewer's concerning into our manuscript, we added a new paragraph just before the "Concluding remarks" section.

"*It is important to remark that the surface of Mexico is near 2 million ${\rm km}^2$. This fact made of our results valid only for the central region of Mexico (few thousands of ${\rm km}^2$), leaving the rest of its surface to address. In addition, Mexico is located at North America, and the ionospheric currents pass through and evolve along the whole American continent. Hence, on one hand, it is required more sources of geomagnetic registers in Mexico and, on the other hand, it is necessary to contextualize the geomagnetic response of Mexico with those present in Northern and Central America, and even South America. For the first case, LANCE is developing a the Network of Geomagnetic Stations Mexico (REGMEX), to monitoring regional geomagnetic response all over Mexico. Whereas, for the case of contextualize the geomagnetic response of Mexico, this is our immediate future work.*"

Additionally, and related to the work we are currently doing, the Reviewer commented that it would be appropriate to add data from Central America. However, in our data search, we did not find public sources in any Central American country. The only data source we know of is the Magnetic Observatory of Chiripa in Costa Rica, whose registered are closed. We were only able to access data from Puerto Rico, which is located in the Caribbean. Therefore, if the Reviewer has access to open/free data from Central America, we would greatly appreciate it the Reviewer would share the sources so that we can contact the data sources and collaborate with them.

Minor points/Author's Response:

1. There seem to be 2 abstracts in this paper.
I apologize for the confusion. The initial abstract that was displayed is not intended for this work but rather for an independent project. I am currently rectifying this error.

2. What is continental territory?
The reviewer is right, I apology for the confusion We removed this part of the writing.

3. Abstract, check the first sentence.
We have opted to conduct a thorough revision of the abstract to enhance its quality.

4. Page 1 Right Column (RC), lines 40-41: Correct sentence
Original sentence:
"In consequence, overlooking the regional factor in GSs may lead to some uncertainties or misinterpretation in the attempt of understand and address the possible effects related to GS events"

reviewed sentence:
"Overlooking these regional factors may lead to uncertainties and misinterpretations when attempting to comprehend and address the potential effects of geomagnetic storm events"

5. Page 1-RC, lines 46-47: Correct sentence

Original sentence:
“Space weather studies for regions within middle and low geomagnetic-latitudes has became of more interest in recent decades.”

reviewed sentence:
“In recent decades, there has been growing interest in regional space weather. Regional space weather studies mainly focuses on identiffed the differences between the local and planetary geomagnetic and ionospheric responses”

6. Page 1-RC, lines 60: replace 'by' with 'in.'
Response: Done

7. Page 2- Left Column (LC), lines 5: replace 'monitoring with 'monitor.'
Response: Done

8. Page 2-LC, lines 10: add 'it.'
Response: Done

9. Page 2-LC, lines 29: correct sentence
Original sentence:
“The charged particles in those cells are drift by the centrifuge and curvature effects of the EMF, condition that induces a polarized electric field ”

reviewed sentence:
“ The charged particles within these cells are carried by the centrifugal and curvature effects of the EMF, resulting in the induction of a polarized electric field”

10. Page 2-LC, lines 37: correct sentence
Original sentence:
“On the other hand, the Ddyn currents are enhances of the polar ionospheric currents due to the precipitation of energetic particles ocurring during the main phase of a GS”

reviewed sentence:
“On the other hand, Ddyn currents represent amplifications of the polar ionospheric currents due to the precipitation of energetic particles during the main phase of a geomagnetic storm”

11. Page 2-LC, lines 43: correct sentence

Original sentence:
“The Coriolis force cause a westward change of direction on these polar-equatorial flows, at mid and low latitudes [...]”
reviewed sentence:
“The Coriolis force induces a westward shift in the direction of these polar-equatorial flows at mid and low latitudes [...]”

12. Page 2-RC, lines 5: correct sentence
Original sentence:

“ […] we first identify differences between regional and planetary geomagnetic activities, with the purpose of isolate regional geomagnetic response during Gss”

Correcter sentence:
“ we first seek to identify disparities between regional and planetary geomagnetic activities to isolate regional geomagnetic responses during geomagnetic storms”

13. Page 2-RC, lines 42: What do the authors mean by 'appreciation.' & 14. Page 2-RC, lines 47: insert 'from' after 'differ.'

Response: I acknowledge the confusion caused by using "appreciation" instead of "these results". Therefore, I have decided to make the necessary corrections to ensure clarity and understanding.

15. Page 2-RC, lines 47. At what point do the planetary and regional geomagnetic indices differ from each other or they are different overall index values?

Response: The general difference, for this 20 events, begins at values around -75 nT; however, we established a threshold of -100 nT, at which point the difference becomes significant.

16. Page 3-LC, lines 43: 'day-to-day variation'

Response: Done

17. Page 3-LC, lines 61: correct sentence.

Original sentence:
“ with D_{others} are ionospheric perturbations different from DP 2 and Ddyn”

Correcter sentence:
“Where D_{others} refers to ionospheric perturbations distinct from the disturbed polar current number 2 ($DP2$) and the disturbed dynamo current (D_{dyn}). These two ionospheric currents are well accepted sources for local geomagnetic fluctuations in low and mid geomagnetic latitudes, as discussed in the Introduction.”

18. Page 4-LC, lines 36: replace 'shadowing' by 'shading.'
Response: Done

19. Page 4-LC, lines 39: 'within'
Response: Done

20. Page 4-LC, lines 40-41: correct sentence

Original sentence:
“ It is important to remark that, due to our study cases might be potentially different each other, the filtering ranges might slightly variate from case to case.”

Correcter sentence:
“ It is important to comment that we manualy identify $Ddyn$'s range by setting the main period and searching potency peaks within the range of possible harmonics. These slightly variations on periods(frequencies) are due to the differences between our study cases, already commented.”

21. Page 4-LC, lines 42: 'vary.'
Response: Done

***22. Is there a reason why the profiles of DP2 and Ddyn in Figure 2c were reconstructed with different frequencies other than those identified before?**

Response:
I apologize, but I am not entirely clear on this question. In Figure 2c, the reconstructed time series exhibits periods/frequencies that align with the highlighted frequency band ranges shown in Figure 2b, which are associated with these ionospheric currents. We have not utilized any other frequency ranges previously.

23. Page 4-RC, lines 5-6: remove 'in' and replace with 'of'. Remove 'that'

Response: Done

24. Page 4-RC, lines 7: 'trigger'

Response: Done

25. Figures: Improve the caption
Response: Done

Extra Modifications:
We added on the body paper the events 3, 6 and 18; besides event 13 as examples in order to be more clear about the process.

So, the article gets Figures 2, 3, 4 & 5 which describes the results for events 3, 6, 13 & 18.

On the other hand, the original Figure 3, now Figure 6 includes all 4 events as subplots considering that what they describe can be shown in smaller panels. On Figure 5 we also decided to take off the error bars in order to avoid confused interpretation of the Figure. Hence, we modified the text which described the error bars on page 4 RC, Lines 61 – 63.