Responses to Editor and Reviewers

General Comments:

Dear Dr. Luis Vieira.

We appreciate for considering our manuscript suitable within the scope of Annales Geophysicae. We also thank the three reviewers and Dr. Joseph Olwendo for the comments and suggestions. Out point-by-point responses and the tracked changes manuscript for the Referee #1 can be found as following:

Reviewer #1:

REVIEWER:**"Review of 'Influence of the semidiurnal lunar tide on the equatorial plasma bubble zonal drifts over Brazil' by Paulino et al (angeo-2021-38). The paper presents an analysis of OI6300 airglow emissions to determine the semidiurnal lunar tide (M2) contribution to the zonal drifts of equatorial plasma bubbles (EPBs). Analysis of the airglow observations demonstrates that the M2 contributes 5% to the EPB zonal drift variability. The M2 contribution to the EPB zonal drift variability is also found to vary with season and solar cycle. EPBs exhibit significant day-to-day variability, which is important to understand due to their negative impacts on various technologies. The present study is thus a useful contribution to present understanding of the EPB variability, and would be suitable for publication. There are, however, several aspects that I believe need to be clarified prior to publication. More detailed specific comments are provided below. "**

AUTHORS: Thank you for revising our manuscript and for the valuable suggestions that certainly will improve our paper.

REVIEWER:**"1. In lines 56-57, the authors state 'The observations were made between September 2000 and April 2007, centered at new moon periods, resulting in thirteen nights of data per month.' The authors should explain why the observations are restricted to the thirteen days of observations that are centered on the new moon periods. I believe that this is due to the instrument being unable to observe EPBs during the full moon. Restricting the data to new moon periods also limits the lunar local times that can be observed, potentially making the fits to the lunar semidiurnal tide less certain. This limitation should be clearly explained in the text."**

AUTHORS: The reviewer is right. That is a technical limitation because the all sky imager is sensitive to the Moon light. We have just explained it in the manuscript. Regarding the "...making the fits to the lunar semidiurnal tide less certain", the reviewer is right as well, however, choosing the 13 day in a month is enough to cover a full period of the oscillation as can be seen in Figure 1-3. Additionally, the presented results used a long period of observation which made possible a confident statistical analysis. Thank you for the comment and we have also added some words on this point in the manuscript.

REVIEWER:**"2. It is unclear based on the description provided in Section 2 if the analysis places any restriction based on geomagnetic activity. This**

should be clarified in the text."

AUTHORS: Thank you for the important comment. We have included the information in the manuscript that there were no magnetic disturbed days from the analysis. The M_2 appeared in the EPB zonal drifts independent of the geomagnetic influence, this is relevant for this work. Furthermore, during the high solar activity, when there is more influence of magnetic storms in the ionosphere, the amplitudes of the M_2 were higher.

REVIEWER:**"3. Results are presented for Southern Hemisphere summer as well as the equinoxes. Is there a reason why results are not presented for winter? "**

AUTHORS: Thank you for the comment. Yes, the EPBs over Brazil have preferred occurrence from September to March. During the winter, the EPBs develop in a few nights (https://doi.org/10.1016/S1364-6826(02)00089-5), which is not statistically significant to compute the M_2. We have also included a statement in the manuscript.

REVIEWER:**"4. One of the conclusions, and intriguing aspects, of the study is the solar cycle dependence, which shows larger M2 amplitudes in the EPB zonal drifts during solar maximum compared to solar minimum. This is opposite what may be expected if the EPB zonal drifts are driven by the in-situ tide that is anticipated to be smaller during solar maximum. I believe that the authors should discuss this result in more detail. In particular, it is important to consider the fact that the analysis was performed for a longer period of solar maximum (September 2000 to December 2002) versus solar minimum (January to April 2007). This has the potential to influence the results and should be clearly discussed. Additional discussions of any previous investigations into the solar cycle variations of the lunar tide in the ionosphere-thermosphere should also be included. "**

AUTHORS: We agree with the Reviewer #1 that it is necessary to expand this discussion. It was the main concern of the other reviewers as well. We have made some comparisons as suggested by the Reviewer #1 and we will revise this topic according to the suggestions of the Reviewers # 2 and # 3 (It will be presented soon). Regarding the second concern, we have used 16 months during the LSA, which we believe to be enough to avoid short term variability in the M_2. However, we agree with the reviewer that it is important to mention this difference in the manuscript.

REVIEWER:**"1. Line 6: 'dependents' should be 'dependent'; 2. Line 21: ?motvement" should be 'movement'; 3. Lines 36-37: The sentence beginning with 'As the PRE (vertical motion) ?' is unclear and should be rewritten; 4. Line 130: 'during he' should be 'during the'; Line 135: '200 to 2007' should be '2000 to 2007'. "**

AUTHORS: We appreciate the correction from the reviewer. We have performed all of them in the manuscript according to the suggestions.

Reviewer #2:

REVIEWER:**"By analyzing the all-sky airglow images taken in Brazil from 2000 to 2007, zonal drift velocity of plasma bubbles are estimated. Based on these velocity data, the authors investigate semidiurnal lunar tide component. This is the topic studied for a long time. This study could provide valuable data. Therefore, this paper is worth publishing in this journal. However, the interpretation and discussion is not enough. Minor revision is needed before its publication. Details are shown below. "**

AUTHORS: We really appreciate the relevant contribution suggested by the reviewer.

REVIEWER:**"In the discussion section, explanation of definition for geomagnetic tide and ionospheric tide is needed. This reviewer considers that this terminology is not suitable because this reviewer understand as follows. "The geomagnetic tide" is the tide in the E region. The neutral wind variations caused by the tide in the E region generate polarization electric field through the E region dynamo to keep divergence free of the electric current. The polarization electric field generated through the E-region dynamo is transmitted to the F region, causing the ExB drift in the F region. On the other hand, "the ionospheric tide" is the tide in the F region. The neutral wind variation caused by the tide in the F region generates polarization electric field through the F region dynamo. The F-region plasma moves by ExB drift due to the polarization electric field. Therefore, this reviewer considers that "the geomagnetic tide" is the tide in the E region, and that "the ionospheric tide" is the tide in the F region. The authors need to explain the mechanism of the geomagnetic and ionospheric tides. – During daytime, E-region conductivity is higher than the F-region conductivity, so that the polarization electric field through the dynamo mechanism is generated mainly in the E region. However, during nighttime, the plasma density in the E-region disappears due to the recombination. The polarization electric field is mainly generated in the F region and the polarization electric field generated in the E region is negligible. The authors need to argue this point. "**

AUTHORS: Thank you for the very didactic explanation. We have revised the discussion considering this suggestion.

REVIEWER:**"first line in abstract, "36.5oW": "o" should be a superscript "**

AUTHORS: Thank you for the suggestion, we have fixed it.

Reviewer #3:

REVIEWER:**"The authors adopted all-sky airglow imager to investigate the zonal drift of EPB and find interesting semidiurnal lunar tide (M2) signatures. The manuscript appears to be a short research letter that only the observational results are provided with inadequate interpretations and discussions."**

AUTHORS: We thank the reviewer for the comments and suggestions.

REVIEWER:**"The authors' discussion on the solar cycle effects is extremely inadequate, a simple 'must be further investigated' is not an excuse. At least, the author needs to explain why the question cannot be solved in this study? What kind of data might need to resolve the question?"**

AUTHORS: We agree with the reviewer that we have not used the best words in this statement, we have revised it. We are sure of the present results and it is not necessary any further data to conclude on the solar dependence of the M_2 in the EPB zonal drifts. What needs to be further studied is the coupling mechanism that is quite complex and it is maybe the "biggest puzzle" for the atmospheric sciences (words from Tsunoda, 2006).

REVIEWER:**"Lines 4-5: Confused with 'the M2 contributes 5.6% to the variability of the EPB zonal drifts'. How the contribution level is determined?"**

AUTHORS: It represents 5.6% of the average EPB zonal drifts. We have clarified it in the manuscript.

REVIEWER:**"Line 33: Be specific about 'nighttime' and 'evening'. Lines 36: Two ?as?."**

AUTHORS: Thank you for the suggestions, but It is correct. During the first hours the night the zonal drifts are higher.

REVIEWER:**"Line 93: What is the meaning of 'combination' Two independent aspects or the combined two effects?"**

AUTHORS: M_2 in the ionosphere responds as the geomagnetic and ionospheric tides. From our point of view, the statement is correct. However, based on the comment of the Reviewer #2, we have improved the discussion on this topic.

REVIEWER:**"Line 106: Rewrite 'Additionally, they showed that the M2 is larger in this region as compared to the geomagnetic contribution from the space perturbations'. Lines 105-107: Two 'Additionally'. Lines 119-120: Rewrite 'as in the temperature (Paulino et al., 2013) as in the zonal wind'. Lines 128-134: Rewrite 'Forbes'. And summary the main idea of this paragraph."**

AUTHORS: Thank you for the suggestions, we have fixed them.

REVIEWER:**"Lines 128-129: What do mean 'differences near the equator' "**

AUTHORS: We have fixed this statement for a better understanding. Thank you for asking.

Reviewer #4 (Dr. Joseph Olwendo):

REVIEWER:**"The paper remain significant in understanding the drivers and structuring 0f ionospheric irregularities once initiated. The paper can be accepted for publications but only after a minor revision to the current state. The minor revision is categorized into major corrections and minor corrections. "**

AUTHORS: Thanks for the contributions from Dr. Joseph Olwendo, who kindly revised our manuscript.

REVIEWER:**"How significant is the 5% value of contribution of M2to the zonal drift velocity? why is the non-negligible. this aspects should be highlighted in the revised manuscript."**

AUTHORS: This contribution is relevant because, on average, it is always present with 5% of the EPB zonal drifts. Additionally, M_2 is one of the important features for the day-to-day variability of the EPB.

REVIEWER:**"what is the scientific explanantion regarding the solar activity and seasonal variations of M2. For example can you expalin why M2 is sttronger during solar max and vice versa."**

AUTHORS: It was the most polemic point of this manuscript. However, there are in the literature a couple of works that have pointed out the geomagnetic lunar tide as solar dependent (e.g., Yamazaki and Kosch, 2014). Regarding the ionospheric tide, there are not many reports on it. Assuming that the M_2 in the EPB zonal drifts is a combination of these two tides (geomagnetic and ionospheric), we expect that the M_2 can be solar dependent as well. Regarding the seasonality, the lunar tide in the MLT is stronger in the December solstice and there were observed enhancement of the M_2 associated with SSW events, which are typical from that period of the year.

REVIEWER:**"apart from M2 which plays only 5% of the driving forces in the zonal drift, which are the other drivers accountiong for 95% in the zonal drift. "**

AUTHORS: The main contribution comes from the solar tide. However, it was observed contributions from other atmospheric waves (gravity and planetary waves, e.g., Abdu et al.,2009, Vadas and Fritts, 2009, Taori et al., 2011, Abdu et al., 2015). There are contributions from the ionosphere-magnetosphere interactions (e.g., Abalde et al., 2009) and we must consider the PRE dynamics (e.g., Kelley and Dao, 2018; Eccles et al., 2015) and the neutral wind daily variation as well (Saito and Maruyama, 2009).

REVIEWER:**"Last but not least, the authors should run the revised manuscript in spelling and grammar check before resubmiiting."**

AUTHORS: Thank you for the suggestion. We have done it.

REVIEWER:**"lines 2-3: "strong day to day .....near the equator" rewrite the sentence to improve clarity lines 13-14: "they consist.....ionosphere. the sentence lacks clarity and must be rewritten. lines 14-15: Changes in lines 13-14 must be matched by a re-**

vison in lines 14-15 too for clarity. lines 20-21: PRE in wrongly defined in this section and must be revised. lines 34: the sentence is hanging and is not well connected to the rest. revise this part. The authors should scrutinize the rest of the articles by rrunning the revised version on specllling and grammar check. the above are just afew glaring cases."

AUTHORS: Thank you for the minor revision. We have revised all of them.

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