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Interactive comment on "Solar-cycle, seasonal, and asymmetric dependencies of thermospheric mass density disturbances due to magnetospheric forcing" *by* Andres Calabia and Shuanggen Jin

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Dear Editor and Reviewers, Thank you very much to Editor and Reviewers for this review where constructive comments and valuable suggestions have greatly improved the quality and content of the manuscript. In the followings, comments and suggestions of the two Reviewers, as well as our replies to them, are given. We hope that the revised version of the manuscript together with our replies, cover the Reviewers' comments appropriately and, of course, your further concerns and advice are appreciated.

Best Regards, Andres Calabia and Shuanggen Jin

Answers to Reviewer 1:

1. In section 2-1, we have briefly summarized previous work, methodology, and included relevant references.

2. We have included a reference on the issue of density normalization.

3. In this work, more data and a revised analysis have been performed with respect to the work done in Calabia and Jin [2016]. For instance, we have included POD-based estimates to fill the data gaps of accelerometer measurements [Calabia and Jin, 2017], and manually excluded outliers caused by, e.g., geomagnetic storms and artifacts in the data processing. These improvements have provided a better representation of the variability with respectCalabia and Jin (2016) results.

4. Since GRACE densities are given along the orbit, we have derived global grids by interpolating the initial values. Calabia and Jin (2016) provide a set of grids in the supporting information.

5. We have separately parameterized the PCA time series in terms of solar-flux, annual, and Local Solar Time dependencies (also include other minor dependencies, e.g., daily Am, P, and K waves). Then, we employ the correlation between each parameterized component and the initial time-series.

6. We employ a constant value of Am=6 to set an arbitrary constant quiet-time value to the parameterization, so we can investigate in detail the magnetospheric contribution in the residuals. The parameterization scheme is based on daily grids, so sub-daily variations are therefore averaged to a daily contribution.

7. The "radiation model" is basically the parameterization scheme (Calabia and Jin,2016) excluding magnetospheric contribution. The frequencies are extracted by frequency analysis (periodogram). Annual, semi-annual, etc variations are included in Fourier series.

8. The residual disturbances for the analysis of this paper are obtained by removing

the “radiation model” from the GRACE-derive densities. In this way, contributions due to solar flux radiation, annual, and LST variations are removed from the time-series.

9. A brief introduction is given for the errors in the processing of the GRACE-derived densities. Further reading can be found in the references.

10. In this work, density residual disturbances have temporal and spatial dimensions. In the time dimension, residual disturbances follow the variations of magnetospheric activity. In the spatial dimension, residual disturbances originate at high latitude regions and propagate towards the equator.

11. In section 2.3, the residual disturbances are computed for different regions (north, equator, south). The benefit of choosing these three regions is the possibility to study the propagation time of density disturbances from high-latitude to equatorial regions.

12. In this manuscript, density residuals and residual disturbance (both are abbreviated with$\rho_r insection2.2)arethesamethings.$

13. The dimension in time and space of the density profiles corresponds to the gridded dimension.

14. Equations 4 and 5 fit the direct residual disturbances. The variable$\rho'_r isthegeneralformofthethreeprofiles(north, equator, south).Equations4and5areth$

15. Figure 5: GRACE-derived densities along the orbit (at 1 sec. interval, these are the initial estimates) have been re-sampled at a resolution of 3 minutes to reduce the size of the file given in supporting information. The gridded data are derived from 1-second sampling estimates. Two sets of grids are derived, one for density estimates and other for measurement-times(at each pixel of the grids). The profiles are derived from these grids. For the correlation analysis, magnetospheric indices are interpolated to the same times given by each corresponding pixel. It could be reasonable to discuss/study sub-daily frequencies but should consider possible additional dependencies (e.g., orbit precession, geographical location).

16. The analysis section has been revised to improve reader understanding.

17. Typos incitations and abbreviations have been revised.

Corrections have been revised according to your suggestions and comments. Here some details and additional clarifications:

Line 13 “weaker variations”-> “smaller amplitudes”.

Line 19 “Dstshows good correlation, while Am and Em are best predictors.”Dst is a worse predictor because does not provide time delay to predict in real-time.

Line 18 “Good correlation” -> “best correlation”. We prefer no adding a number since the values compared to previous authors might lead to misunderstanding of its actual assessment. Explicitly, “none of the previous authors have investigated a sufficiently large and continuous time-series of observations, at least to complete a solar cycle, while their statistical analyses were focused only on collections of large storms”. In this scheme, the correlation index for a complete time-series provides lower correlation values than that performed by a collection of events.

Line 30-44 CIRs and CEMs are briefly introduced here to explain the origin of short-term density disturbances.

Lines 46-51. Added explanation: “Aerodynamic-drag associated with neutral-density fluctuations resulting from upper atmospheric expansion/contraction in response to variable solar and geomagnetic activity, increases drag and decelerates Low Earth Orbits, the dwindling lifespan of space-assets, and making tracking difficult.”

In Figure 1, we consider more convenient to put the legend inside the plot to make the graphic bigger.

In Figure 4, we do not use bold font in legend and labels. The fonts might appear ticker due to software issues.

In Table 2, we have removed the column for the north profile. Note that north and equator profiles have not been parameterized for annual variation.

Figure 8 (and its discussion starting at line 344): Note that this work does not study the "absolute" over-estimation of different density models with respect to different in-situ measurements as done by other studies. Instead, it analyzes and obtains 10-year "profiles of density disturbances" from models in the same way as we have done with GRACE estimates.

Please also note the supplement to this comment:
https://www.ann-geophys-discuss.net/angeo-2019-78/angeo-2019-78-AC1-supplement.pdf

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