Interactive comment on "Lower Thermosphere response to solar activity: an EMD analysis of GOCE 2009–2012 data" *by* Alberto Bigazzi et al.

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The authors are grateful to the anonymous Referee 2 for careful reading and commenting of our research paper. We submit our proposals clarifying the points raised, reporting below the Referee Comments as "RC" and our response (Authors' Response) as "AR". In the resubmitted paper, new text is emphasises as bold text.

General comments: For the readers not familiar with, yet interested to further dwell into the EMD technique, we have added further references and new text in Paragraph 4, giving further explanation and context, still striving not to make the discussion too technical.

Specific comments:

RC1 In figure 1 there are significant changes of altitude which are not explained in the text. May they influence data analyses (because one of the main reasons of higher error in the third time zone is the rapid changing of satellite altitude)? AR1: At line 80 in the text we described the changes in satellite altitude and pointed the reader to detailed Mission profile of Fig 1. At line 92 we mentioned the orbit lowering campaign and the relation to the rise in density. As the Referee suggests, these changes in altitude are significant and do influence data analysis, as stated in the caption of Fig. 11. The caption in Fig. 12 also reported a similar comment. In the Conclusions, at line 180, we stated: "During high solar activity, error increases to over 10

We understand that these connections may have been too scattered within the text. We have therefore re-written the discussion after line 80 to better explain and connect the Low-Mission phase with the High solar activity period. We also add a new figure as Figure 12, that is a version of Figure 11 where density signal has been de-trended in the orbit lowering phase, to allow better visual comparison between the density signal and the synthesized signal. Figure is attached to this response. At the end of Par. 5, we have added a discussion of this new Figure.

RC2. In figure 3 there is a subplot (time 534.4 – 535) which is also not mentioned in the text. And what is the nature of obvious periodic oscillations? AR2 Regarding oscillations, we include a mention in the text, besides the one that was already present in Fig3's caption ("In the inset, 10 orbits are plotted, showing the high-frequency fluctuations of density due to satellite orbit, lasting around 90 minutes"). Caption has been updated.

RC3. In figure 4 I suggest correct numbering (last plot is e) but in alphabetic ordering inshould be d)) and to add a) – d) to the plots (it will be easier to understand whatis what) AR3 Implemented as requested. Updated figure is attached.

RC4. It is not commented what data are presented in figure 5 (second and third plot).Here density is averages, but for what time? Daily as in figure 6? AR4 Figure

caption shall be updated as: "Comparison of time series for full-mission thermospheric density, and solar indices Ap, F10.7 and MgII. Top panel: density (full dataset, blue line, and daily averaged, black line) with the Ap index (red line). Middle and bottom panels: daily averaged density (blue) and F10.7 and MgII indices (red), respectively."

RC5. First plot of figure 6 shows "correlation" of density and Ap index, but used averaged index. Does it make sense because previously it was shown that Ap correlates with fast variations. I think that in this plot better to show correlation with instantaneous Ap or may be skip this plot. Moreover, it seems strange to fit with line such field of dots. AR5 We agree with referee that figure 6 is not essential to the development of the paper and will therefore be removed altogether.

RC6. Line 175, it is difficult to understand conclusion and the difference between low and high activity. From data it seems that for all periods Ap is needed to get fast impulsive events and solar flux proxies to get low frequency component of density changing. And from table 1 it is seen that all IMP of Ap are used and low frequency components of F10.7 or MgII are needed for all time intervals. AR6 We have re-written that part of the conclusions clarifying the role of Ap index in all three periods, compared with the radiative components.

RC7. To show efficiency of the method to estimate atmospheric density it would be interesting how the function obtained based on one dataset allows to calculate density in another dates. For example, calculate and optimize function using 2009 or 2010 data and apply it to indices in 2011 to get density and compare with measurements. If error is small it shows that method works, if not this can be explained by different solar activity of other reasons. Now you use the same data to get function and analyze its quality. AR7: Forecasting capability is indeed an important issue. We are working with people who do orbital calculation of debris, in order to test the forecasting capability of our analysis. This is, though, a broader scope than the current paper, whose main point was limited to presenting the GOCE density dataset, the EMD analysis tool and the capability of the MgII index combined with Ap to represent the thermospheric density

data. We have addressed this topic in the updated final conclusions.

RC8. Another important thing is that it should be mentioned that this works for a definite altitude. For different altitude this model should be modified, may be measurements are needed. And interesting question is what makes a greater contribution to the error in the third time interval: increased solar activity or a change in the height of the apparatus? AR8: Conclusions have been restructured to address referee's comments.

RC9 Technical corrections. Line 102 typo a a -> a Line 164 capturedd -> captured AR9 Implemented
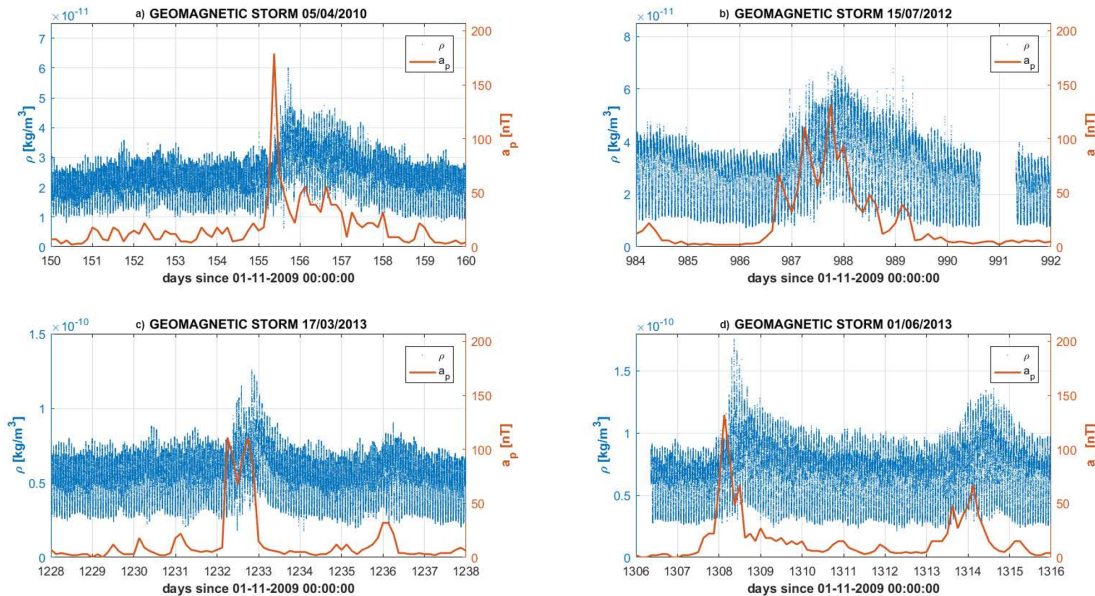
Fig. 1. Thermospheric density ρ (blue line) and a_p index (red line) during four geo-magnetic storms occurred in the course of the GOCE mission. From Top-Left to Bottom-Right: a) 05/04/2010 [day 155];

Whole Mission : σ = 11.2489%

density ρ [kg/m³]

days since 01-11-2009 00:00:00
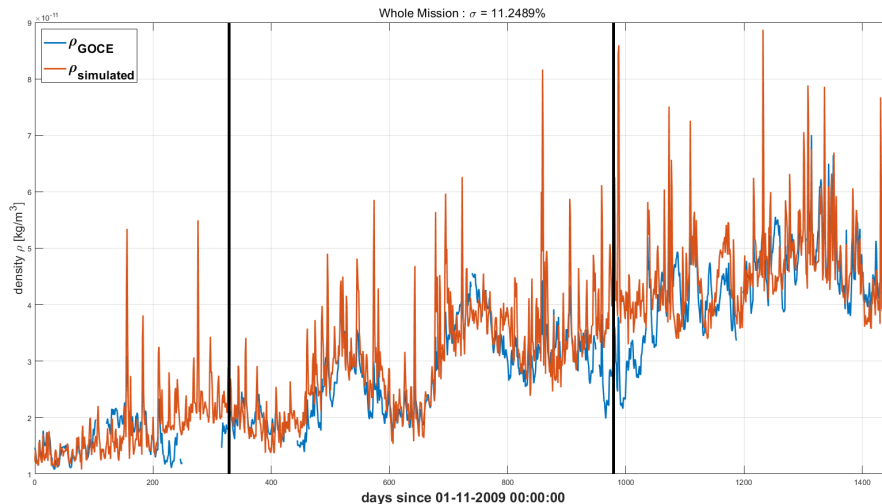
Fig. 2. Effect of orbit lowering on the third, high solar activity period, \from Aug, 1st 2012. Density data (blue line), as shown in Figure~\ref{fig_Recomb_Ap_MaII_F107_full}, have been de-trended to subtrac