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Interactive comment on "From the Sun to the Earth: August 25, 2018 geomagnetic storm effects" *by* Mirko Piersanti et al.

Anonymous Referee #2

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Review report on the manuscript "From the Sun to the Earth: August 25, 2018 geomagnetic storm effects", submitted to Annales Geophysicae by Piersanti et al. for consideration of publication.

Manuscript summary

This manuscript deals with the effects caused by a geomagnetic storm associated with solar perturbations (CME, CIR, HSS) on the geospace environment and on the ground in the period 20-27 August 2018. The authors tracked a CME detected on the Sun and estimated its speed and travel time to 1 AU. The authors then used multi-spacecraft and multi-instrument analyses to study the chain reaction of geospace currents to these drivers and their effects on modern technological systems. The authors also looked at GPS data to evaluate the impact of the storm on these very important systems.

Specifically, the authors looked at geosynchronous, LEO, and ground magnetic field data. Additionally, the authors estimated coefficient/indices for GICs associated with this storm. By comparing these effects to the well-known 2015 St. Patrick's Day storm, which was slightly more intense than the August 2018 storm, the authors concluded that (i) effects on GPS were more severe in 2015; but (ii) effects on GICs were more severe in 2018. These were perhaps the most important results found by the authors at least from a space weather-related standpoint. As a result, intensities of geomagnetic storms can't be used as a standalone parameter to predict and forecast space weather effects on technological infrastructure.

I think the paper is well-written and chronologically organized; this type of investigation, i.e., analyses of chain response characterized by multi-instrument investigations, are very important to advance our knowledge of space weather phenomena. However, I think the paper can be improved if the authors take in consideration my general and specific comments listed below.

General comments

1. The paper can be significantly improved if the authors look more carefully into the driver effects. For example, the authors mention the CME observed on 20 August was a very slow, and consequently weak, CME. Therefore, this kind of CME would drive a very weak IP shock in its leading edge, if any, while traveling in the heliosphere. However, given the IMF and solar wind data detected at $\sim$L1 presented by the authors in Figure 2, I can't tell there is a fast forward interplanetary shock there. There is no clear positive jumps in solar wind parameters (T, Np, V) and IMF (B). A positive sudden impulse is clearly and usually seen in ground magnetometer data in response to an IP shock impact. However, I could not see a clear SI event when I plotted SYM-H here on my side, neither can I see a clear SI signature in SYM-H data shown in the left column of figure 9. Please clarify this: where is the shock around L1? If there is one, does it clearly satisfy the Rankine-Hugoniot conditions? This is very important because this would impact your discussion of inward magnetopause motion (from 10 to 7 Re,

approximately). As it it I think it was because of magnetopause erosion caused by the gradual depletion of IMF Bz, which is not shown in the manuscript.

2. Now, still looking at Figure 2, there is something I think ins't clear: What do the edges of the light red highlighted area indicate? The IP shock onset or the front boundary of the magnetic cloud? As a matter of fact, according to the CME list provided by Ian Richardson (http://www.srl.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm#(a)), the CME of 25 August 2018 detected at L1 did not have a magnetic cloud associated with it. Can you clearly say why your CME had a magnetic cloud, even though it was a weak CME and most likely did not drive a shock in its front edge at 1 AU?

3. According to Figure 2 and Figure 3, there was a CIR/HSS right after the CME. If the geomagnetic storm of 25-26 August 2018 occurred as a result of the impacts of a CME and a CIR back-to-back, why possible effects of these combined rivers are not discussed in the text? By looking at the SYM-H plot (Figure 9), one can speculate that the magnetosphere was starting to recover from the CME when the CIR arrived. Does this have any impacts on the subsequent geomagnetic activity? Do you think SYM-H effects were amplified with the CIR arrival? This might explain why the GIC effects in 2018 storm were stronger than the effects in the 2015 storm. However, it is very common to see a clear SI signature preceding a strong geomagnetic storm, which did not occur on 25 August 2018. In other words, does the CIR play any roles in increasing the storm effects discussed in the manuscript?

Specific comments

1. Line 12. Please explicitly state that this is the 2015 St. Patrick's Day storm.

2. Lines 17-18. The way this sentence is written, one can wrongly understand that geomagnetic storms are only caused by CMEs. Please re-write this sentence to eliminate this inaccurate statement.

3. Line 18: The reference Piersanti et al. (2017b) doesn't appear in the reference list. I didn't check all references; please do so.

4. Line 27. Change "the Sun" to "solar".

5. Lines 27-28. Sun energy directly deposited in the polar ionosphere. Do you mean EUV radiation? If so, EUV radiation is directly deposited by the Sun in all dayside latitudes. I think what you mean is that solar radiation increases dayside conductivity which in turn facilitates the flow of electric current in the ionosphere? Please clarify this. It looks awkward to read.

6. Line 37. Hapgood (2019) discusses GIC effects of the May 1921 superstorm that were associated with fires in New York City. Therefore, space weather related effects can be dangerous to human life. If the authors are interested, here is the reference:

Hapgood, M. (2019), The Great Storm of May 1921: An Exemplar of a Dangerous Space Weather Event, Space Weather, 17 (7), 950–975, doi:10.1029/2019SW002195.

7. Line 41. Please state what defines a G3 geomagnetic storm.

8. Line 63. Please give a number for the reader to have an idea of how fast a slow CME goes.

9. Line 89. Add "dynamic" before "pressure".

10. Line 114. Change "overtook" to "overtaken". Same in line 360.

11. Figure 3. It is hard to see Venus as represented by the green triangle.

12. Line 126. "Possibly" reads better than ""probably.

13. Line 156. Should "IP2" be "IPS"?

14. Line 215. Please explicitly state of loss of lock on GPS satellites means. Add a reference if appropriate.

15. Line 219. Please state that storm intensity is represented by Dst/SYM-H data.

16. Line 246: Remove a "the" (end of line).

17. Line 254. The traditional reference for the SYM-H index is Iyemori (1990),

Iyemori, T. (1990), Storm-time magnetospheric currents inferred from mid–latitude geomagnetic field variations, Journal of Geomagnetism and Geoelectricity, 42(11), 1249–1265, doi:10.5636/jgg.42.1249.

18. Line 260. Do you mean you are removing the background magnetic field computed by the IGRF model? Please clarify.

19. Line 274. "on August" should be "On August".

20. Line 297. "on turn" should be "in turn".

21. Line 312. Please include a table with the stations' names and abbreviations and refer to it instead of referring to the IAGA website.

22. Line 346. Change "has been" too "was". No continuity here.

23. Line 413. Change "leaded" to "led".

24. Line 431. Change "comprehending" to "understanding".

25. My apologies, but I read in a few places mentions to "polar electrojets". Do you mean auroral electrojets? Usually, these electric currents have their effects expressed by the AU, AL, and AE indices. If so, please clarify and change it accordingly. Additionally, it would be interesting to plot these indices in another column in Figure 9.

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